MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XC. FEBRUARY 14, 1930. No. 4

ANNUAL GENERAL MEETING.

Dr. A. C. D. CROMMELIN, PRESIDENT, in the Chair.

The Minutes of the preceding Annual General Meeting were read and confirmed.

The Report of the Auditors of the Treasurer's accounts for the year 1929 was read, and is given on p. 351.

The Annual Report of the Council was partly read.

The President delivered an Address on the award of the Gold Medal to Dr. J. S. Plaskett, to whom the Medal had been awarded for his valuable observations of Stellar Radial Velocities and the important conclusions derived from them.

The President announced that Dr. Plaskett would deliver the George Darwin Lecture at the Ordinary Meeting of the Society on May 9, and that the subject of the lecture would be "The High Temperature Stars."

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 478.

During an interval, Professor Turner spoke on the proposed 200-inch telescope of the Californian Institute of Technology; Mr. F. J. Hargreaves spoke on the present apparition of Jupiter; and Mr. Newton gave an account of the Spectrohelioscope at Greenwich.

The thanks of the Meeting were given to the retiring Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

The election by the Council of the following Fellows was duly confirmed :—

Joseph Bevan Braithwaite, Lea Wood, Woodside Avenue, Muswell Hill, London, N. 10;

Walter Frederick Kibble, M.A., Professor of Mathematics, Christian College, Madras, S. India;

Emlyn Samuel Phillips, 40 Barrington Road, London, N. 8; and

John Henry Wills, B.Sc., Bethany House School, Goudhurst, and Trevelyan, Bodmin, Cornwall.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Samuel Forster Grace, D.Sc., Lecturer in Applied Mathematics in the University of Liverpool, Thornfield, Huyton, Liverpool (proposed by J. Proudman);

Theodore Mackenzie, 46 Market Street, Grahamstown, S. Africa (proposed by R. T. A. Innes);

Gordon Oliver, M.Sc., Rivelin, Pwll Glas, Mold, N. Wales (proposed by J. A. Lloyd);

John William Robinson Punch, Ellerstang, Castleton, Yorks (proposed by S. Brodetsky);

Theodor Martin William Strong, B.Sc., Oak Cottage, Much Hadham, Herts (proposed by H. Jeffreys); and

Henry Major Twiselton, M.A., 2 Aldworth Grove, London, S.E. 13 (proposed by A. S. Eddington).

Report of the Council to the Hundred and Tenth Annual General Meeting of the Society.

Progress and Present State of the Society.

	Patron	Institutional Members	Honorary Member	Fellows: Compounders	Fellows: Annual Subscribers	Associates	Total
1928 December 31	1	2	1	222	680	49	955
Since elected	...	+1	...	+ 3	+36	...	...
Deceased	...	...	...	−11	−11	−2	...
Resigned	...	...	...	...	−17	...	...
Since compounded	...	...	...	+ 6	− 6	...	...
Removed from list	...	...	...	...	− 4	...	...
1929 December 31	1	3	1	220	678	47	950

(Five Associates are also Fellows, and are therefore counted twice in the above table.)

Mr. Reynolds's Cash Account as Treasurer of the Royal

RECEIVED.

	£ s. d.	£ s. d.
Balances, 1929 January 1:—		
In hand of Assistant Secretary on Petty Cash Account	17 12 7	
At Bankers', on Current Account ... £542 16 9		
Add Due from "C" Account 12 12 6	555 9 3	
At Bankers', on Deposit Account (including Special Fund, £215, 12s. 5d.)	391 3 0	
At Bankers', on "C" Account £120 13 7		
Deduct Due to General Account ... 12 12 6	108 1 1	
		1072 5 11
Received on account of Dividends, etc.:—		
£1250 Metropolitan 3% Stock	37 10 0	
£2000 Swansea Corporation 3½% Stock	70 0 0	
£2287, 6s. 9d. East Indian Railway 3% Stock ...	54 17 10	
£5125 London, Midland and Scottish Railway 4% Debenture Stock	164 0 0	
£750 London, Midland and Scottish Railway 4% Consolidated Preference Stock	24 0 0	
£2400 Gas Light & Coke Co. 3% Debenture Stock ...	57 12 0	
£2000 Commercial Gas Co. 3% Debenture Stock ...	48 0 0	
£4377, 12s. 6d. War Loan Inscribed 5% Stock ...	218 17 6	
£500 National War Bonds, 1929 (half-year's dividend)	12 10 0	
£419, 17s. 11d. Conversion Loan 4½% Stock, 1940/44	15 2 4	
£695, 16s. Conversion Loan 3½% Stock, 1961 ...	21 18 4	
Interest on Deposit Account	14 3 3	
Income Tax refunded, 1926 April–1929 April (General and Special Funds)	279 19 11	
	1018 11 2	
Sales of Publications:—		
At Society's Rooms £164 7 0		
At Wheldon & Wesley's 183 0 9		
Reprints 76 13 6	424 1 3	
Sale of Photographs	46 19 1	
Miscellaneous Receipts:—		
London Mathematical Society, expenses of Meetings, etc. £30 0 0		
Assist. Sec. and Clerk, Pension Premiums 19 5 0		
Postages repaid, and Use of Telephone 3 17 3		
Sale of Duplicate Books and Waste Paper 4 5 0	57 7 3	
Legacy from the late Mr. W. J. Thorrowgood	100 0 0	
		1646 18 9
Refund from "C" Account for Jackson-Gwilt Medals, 1928		12 12 6
Redemption of National War Bond, 1929 (Special Fund) ...		525 0 0
Received on account of Subscriptions:—		
567 Annual Contributions (including 3 Institutional Membership fees)	1190 14 0	
21 Annual Contributions 1930, paid in advance ...	44 2 0	
40 Admission Fees (including 1 due in 1928)	84 0 0	
37 First Contributions (including 1 due in 1928) ...	72 9 0	
Arrears paid off:—		
9 for 1927 ... ... £18 18 0		
36 for 1928 ... ... 75 12 0	94 10 0	
		1485 15 0
Compositions		161 14 0
Amount received in advance of Election 1930 January		3 0 0
Donations to Special Fund		16 1 0
Trust Fund Dividends:—		
£1212, 13s. 3d. East Indian Railway 3% Stock ...	29 2 2	
£542, 18s. 2d. India 3½% Stock	19 0 0	
£1934, 10s. 2d. 5% War Stock, 1929/47	96 14 6	
Income Tax refunded, 1926 April–1929 April ...	21 16 7	
		166 13 3
		£5090 0 5

Examined and found correct.

(Signed) T. WHITWELL.

1930 *January* 28. W. M. WITCHELL.

Astronomical Society, from 1929 January 1 to December 31.

PAID.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
Clerk: Salary	170	0	0			
Assistant Secretary and Clerk for work done for London Mathematical Society in 1928	10	0	0			
Pension Premiums for Assistant Secretary and Clerk ...	57	15	0			
Porter and Wife: Wages	146	0	0			
Health and Unemployment Insurance	6	11	2			
Pension, Mrs. Barrett	39	0	0	679	6	2
Licence for Porter	0	15	0			
Fire and Accident Insurance	15	15	3			
Telephone	13	10	6			
Telegraphic Address and Time Signal	7	2	8			
Water Rate	12	17	3	50	0	8
Postage and Packing (including postage of *Monthly Notices*, etc., £92, os. 1d.)				136	8	6
Printing, etc.:—						
Monthly Notices (Vol. 89, Nos. 1–9)	907	2	10			
Geophysical Supplements (Vol. 2, Nos. 3, 4)	144	14	10			
Memoirs (Vol. 64, pt. 5; App. to Vol. 65)	137	19	3			
Reprints	72	18	9			
List of Fellows	43	18	0			
Charts (J. M. Baldwin)	7	12	2			
Miscellaneous	57	13	6			
Photo-engraving:—						
Monthly Notices £71 2 9						
Geophysical Supplements 1 17 6	73	0	3	1444	19	7
Reproduction of Photographs for sale				55	18	3
Stationery and Office Expenses	24	12	1			
Library Equipment and Binding	51	16	11			
Subscription to International Telegrams Bureau	6	2	2			
Coal, Gas, Electric Light, Firewood	100	19	9			
House Cleaning and Laundry	20	5	9			
Repair of Harrison Clock	23	11	9			
Fittings and Repairs	29	12	6			
Kitchen Range	41	19	6			
Electric Water-Heater	20	10	0			
Transport and Erection of Thorrowgood Telescope ...	96	15	3			
Legal Charges	2	2	0			
Miscellaneous Expenditure	10	8	9			
Expenses of R.A.S. Meetings	18	8	7			
Expenses of Geophysical Meetings	7	5	11			
Expenses of L.M.S. Meetings	5	19	0			
				460	9	11
Bank Charges and Cheque-Book				0	19	2
				2828	2	3
Purchase of £525 5% War Stock (Special Fund)				532	6	5
Expenditure on Trust Accounts:—						
George Darwin Lecture	49	8	2			
Turnor and Horrocks Fund } Library	17	12	11			
Harry Watson Fund ... } Library	100	1	3			
Lee and Janson Fund	20	0	0			
Jackson-Gwilt Fund (Refund to General Account for Medals, 1928)	12	12	6			
Cheque-Book debited to "C" Account	0	16	8	200	11	6
Balances, 1929 December 31:—						
In hand of Assistant Secretary on Petty Cash Account	17	17	0			
At Bankers', on Current Account	1025	11	4			
At Bankers', on Deposit Account (including £223, 6s. 0d., Special Fund)	398	16	7			
At Bankers', on "C" Account (Trust Funds) ...	86	15	4			
				1529	0	3
				£5090	0	5

REVENUE

	£	s.	d.	£	s.	d.
To General Expenditure as per Cash Account	2828	2	3			
,, Reserve for Accounts due but not presented	290	0	0			
	3118	2	3			
Less Reserve for Accounts due 1928 now written back	255	0	0			
				2863	2	3
,, Composition Fees Reserve Fund:—						
Transferred to Fund during 1929	161	14	0			
Less 6 per cent. of Fund transferred to Revenue ...	9	14	0			
				152	0	0
,, 13 Annual Contributions in Arrear written off ...	27	6	0			
,, 8 Annual Contributions 1929 written off as per contra	16	16	0			
				44	2	0
Excess of Income over Expenditure	...		...	23	17	10
				£3083	2	1

Examined and found correct.

(Signed) T. WHITWELL.
W. M. WITCHELL.

1930 *January* 30.

ACCOUNT, 1929.

		£	s.	d.	£	s.	d.
By Subscriptions—							
567	Annual Contributions for 1929 (including 3 Institutional Membership Fees)	1190	14	0			
20	ditto, paid in advance in 1928, and now matured	42	0	0			
75	ditto, outstanding	157	10	0			
8	Contributions for 1929 due, but unpaid, in respect of Fellows died, resigned, or names removed, and written off per contra ...	16	16	0			
					1407	0	0
,, 32	First Contributions, 1929, at 2 guineas ...	67	4	0			
4	ditto, at 1 guinea	4	4	0			
36					71	8	0
,, 39	Admission Fees, 1929	...		...	81	18	0
,, 4	Composition Fees (initial)	126	0	0			
5	ditto, reduced	35	14	0			
9					161	14	0
,, Donation to Special Fund transferred to General Account					1	1	0
,, Sundry Debtors, 1929					12	18	5
,, Dividends, Sales of Publications and Photographs, and Miscellaneous Receipts, as per Cash Account		1646	18	9			
Less Payments due 1927-28 (£73, 2s. 0d., *less* £1, 4s. 6d. still outstanding)	£71 17 6						
Advance payments for *Monthly Notices* (Vol. 90, Nos. 2–9) ...	41 5 4						
Income Tax 1926 April–1928 December refunded	241 10 11						
		354	13	9			
					1292	5	0
,, Income Tax (General Fund) deducted at source 1929 April 6 to December 31, not yet refunded					54	17	8
					£3083	2	1

BALANCE SHEET,

LIABILITIES.

	£ s. d.	£ s. d.
23½ Subscriptions 1930, paid in 1928 and 1929	49 7 0	
1 Subscription 1931, paid in 1928	2 2 0	
Amount received in advance of election 1930 January ...	3 0 0	
		54 9 0
Sundry Creditors for Accounts due but not presented ...		290 0 0
Cash Balances (Income) of Trust Funds—		
Turnor and Horrocks Fund	9 7 11	
Harry Watson Fund	10 12 5	
Lee and Janson Fund	16 15 6	
Hannah Jackson Fund	26 2 1	
George Darwin Lectureship Fund	24 14 1	
	87 12 0	
Less debited for Cheque-Book...	16 8	
		86 15 4
Trust Funds (Capital), as per contra		2,949 17 0
Special Fund—		
As at 1928 December 31 ... ... £1,672 14 6		
Less transferred to General Account in 1928, now written back ... 16 10		
	1671 17 8	
Donations in 1929 ... ... £16 1 0		
Less transferred to General Account in 1929 ... ... 1 1 0		
	15 0 0	
	1686 17 8	
Deduct Difference between original purchase price of 1929 War Bond and repaid amount	6 5 3	
		1680 12 5
Income Tax on Trust Funds, 1929 April–December, not yet refunded, as per contra		5 9 1
Income Tax due to be refunded from General Account to Special Fund for 1926 and 1927		5 13 3
Composition Fees Reserve :—		
Fund at 1929 December 31	161 14 0	
Less 6 per cent. transferred to current revenue ...	9 14 0	
		152 0 0
Advance Payments for *Monthly Notices*, Vol. 90, Nos. 2–9.		41 5 4
General Fund—As at 1928 December 31	15,899 1 4	
Add— Amount transferred from Special Fund in 1928 now brought forward	16 10	
Add— Excess of Income over Expenditure, 1929 ...	23 17 10	
	15,923 16 0	
Less Excess payment to Trust Funds now written off	0 0 1	
		15,923 15 11
		£21,189 17 4

Examined and found correct.

(Signed) T. WHITWELL.

W. M. WITCHELL.

1930 *January* 30.

1929 *December* 31.

ASSETS.

	£ s. d.	£ s. d.
Sundry Debtors for Subscriptions in Arrears—		
17 for 1928	35 14 0	
75 for 1929	157 10 0	
		193 4 0
Sundry Debtors, 1928		1 4 6
Sundry Debtors, 1929—		
Due for Publications and Reprints	7 18 9	
Due for Photographs	4 8 10	
Due for Postages and Packing	10 10	
		12 18 5
Investments, General Fund, valued as on 1922 December 29		14,986 0 0
Investments of Special Fund, valued as at date of purchase		
£695, 16s. Conversion Loan 3½ per cent. 1961 ...	525 0 0	
£419, 17s 11d. Conversion Loan 4½ per cent. 1940–44	400 0 0	
£525 War Stock 5 per cent. 1929–47	532 6 5	
		1457 6 5
Investments of Trust Funds, valued as on 1922 December 29 or date of purchase if later ...		2,949 17 0
Income Tax 1929 April 6–December 31, not yet refunded—		
General Fund	54 17 8	
Trust Funds	5 9 1	
		60 6 9
Sundry Balances—		
Cash at Bank on Current Account	1025 11 4	
,, ,, Deposit (including Special Fund, £223, 6s. 0d.)	398 16 7	
,, ,, "C" Account (Trust Funds) ...	86 15 4	
Cash in hand of Assistant Secretary	17 17 0	
		1,529 0 3
		£21,189 17 4

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.
Furniture, etc.
Stock of Publications and Photographs.
One Gold Medal.
Five Bronze (Jackson-Gwilt) Medals.

INVESTMENTS.

As at 1929 December 31.

GENERAL FUND.

£1250 Metropolitan 3-per-cent. Stock.

£2000 Swansea Corporation 3½-per-cent. Stock.

£2287, 6s. 9d. East Indian Railway 3-per-cent. Debenture Stock.*

£5125 London, Midland and Scottish Railway 4-per-cent. Debenture Stock.*

£750 London, Midland and Scottish Railway 4-per-cent. Consolidated Preference Stock.*

£2400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.*

£2000 Commercial Gas Co. 3-per-cent. Debenture Stock.*

£3852, 12s. 6d. 5-per-cent. War Loan Inscribed Stock, 1929–47.

GROVE-HILLS SPECIAL FUND.

£525 5-per-cent. War Loan Inscribed Stock, 1929–47.

£419, 17s. 11d. Conversion Loan 4½-per-cent., 1940/44.*

£695, 16s. Conversion Loan 3½-per-cent., 1961.

FIVE TRUST FUNDS.

£1212, 13s. 3d. East Indian Railway 3-per-cent. Stock.*

£542, 18s. 2d. India 3½-per-cent. Stock.

£1934, 10s. 2d. 5-per-cent. War Loan Inscribed Stock, 1929–47.

* Taxed at source.

Report of the Auditors for the Year 1929.

We have examined the Treasurer's account of receipts and expenditure, and the Revenue Account and Balance Sheet, for the calendar year 1929, and have certified them to be correct. The investment holdings have been certified either by the Bank of England or by the Westminster Bank.

It will be observed that a sum of £152 has been held in reserve from the year's receipts for Compositions. The principles underlying this reserve are discussed in the appendix to our Report.

Notwithstanding the fact that such a sum has been withheld from current revenue, the Revenue Account shows a small excess of income over expenditure of about £24. A number of minor causes have contributed to this result, and an interesting comparison is afforded between the current year's Cash and Revenue Accounts and those for 1928.

Among the points in these accounts to which attention may be directed is the item of Sales of Publications at the Society's Rooms, which has increased from £17 in 1928 to £164 in 1929. This large increase follows the withdrawal of the sales agency for the Society's publications from Messrs. Wheldon & Wesley.

We are happy to be able to record that a sum of over £300 has been refunded by the Inland Revenue Department in respect of income tax deducted at source since 1926. This repayment of tax has not, of course, affected the balance on the Revenue Account, as credit had already been taken for the money year by year in the hope, now fortunately realised, that the question would be decided in favour of the Society. The receipt of the refund has accordingly made good an otherwise doubtful asset included in previous Balance Sheets.

A point to which we feel impelled to direct attention is the magnitude of the cash balance held on current account. Whilst it is necessary to retain fluid resources in anticipation of definite future expenditure, we feel that the strong position of the Society would fully justify transferring a considerable portion of the current balance to deposit or to interest-bearing securities. The Banks are prepared to offer ready facilities by way of overdraft against such deposits or securities in order to meet unexpected expenditure, and the increased revenue which the Society might enjoy from such investments could well amount to the not inconsiderable sum of £20 or £25 per annum.

The necessity for a continuous scrutiny of the amount of cash held to current account is emphasised by the fact that receipts from Compositions are in future to be placed to reserve, which will, if the reserve is to be an effective one, necessitate their transfer, from time to time, from the current account to a permanent form of investment.

The investments of the General Fund stand in the Balance Sheet at the market prices ruling at the end of 1922, and although this figure is still substantially correct, a small depreciation in their value has taken place.

Owing to an error on the part of the Bank on the last day of the year, the cost of a cheque book was debited to "C" account instead of to the General Account. The necessary cash adjustment will fall to be made in 1930.

In 1928 the sum of 16s. 10d. was transferred from the Special Fund to the General Account, but although the amount was dealt with in the account of the Special Fund, the transaction was not completed in the General Accounts. The necessary adjusting entries have been included in the Balance Sheet for 1929.

In the allocation of recovered income tax, 1d. too much was transferred to the Trust Funds, and as it would have been impracticable to effect a cash adjustment of so small an amount between the two accounts, the sum has been written off the General Fund to the advantage of the Trust Funds.

A list of defaulters has been placed on the table, and contains the names of those Fellows who are in arrear for sums that were due on 1929 January 1, with the amount due against each Fellow's name.

The books, instruments, and other effects on the premises of the Society appear to be in satisfactory order. The Thorrowgood telescope has been lent to Cambridge Observatory for an initial period of ten years, and an item in respect of its transport and erection appears in the Cash Account. The charge has been covered by the monetary bequest that Mr. Thorrowgood made for this purpose.

The checking of the books on the shelves of the Main and Upper Libraries is now complete, and has revealed the absence of the following volumes :—

1. Watson, *Theoretical Astronomy* (1892).
2. Sebastian Munster, *Rudimenta Mathematica* (1551).
3. Sédillot, *Prolégomènes des tables astronomiques d'Oloug-Beg* (1847).
4. ——, Ditto, *Traduction et commentaire* (1853).
5. W. H. Pickering, *Mars* (1921).
6. Flammarion, *Vie de Copernic* (1872).
7. *Archimedis quæ supersunt omnia, cum Eutocii Ascalonitæ commentariis, ex recensione J. Torelli.* [Greek and Latin] (1792).

The absence of these volumes calls attention to the necessity for the strict observance of the rules of the Library, and particularly that which directs that Fellows must sign for all books borrowed.

We desire to record our indebtedness to the Assistant Secretary for the facilities that have been accorded to us during the audit.

(Signed) T. Whitwell.
W. M. Witchell.

1930 *February* 9.

Appendix to Auditors' Report.

The Treatment of Composition Fees in the Annual Accounts.

From time to time attention has been drawn in the Auditors' Reports to the practice, common to many Societies as well as our own, of treating Compositions as current revenue.

The Council has now resolved that " the whole of the receipts for Composition fees should be placed to a Composition Reserve Fund, and that at the end of each year 6 per cent. of the total amount of the Fund should be credited to revenue."

It is proposed to examine briefly what will be the effect of this resolution on the annual accounts and on the Society's annual revenue.

The Cash Account will, of course, be unaffected, the Compositions appearing as a receipt in the usual way.

In the Revenue Account, however, although these Compositions will appear as a receipt there will in future be included on the expenditure side an exactly balancing item transferring the whole of these receipts to the Composition Fees Reserve Fund.

After these receipts have been transferred to the Fund, 6 per cent. of its amount will then be taken and included in the Revenue Account on the receipts side as " transferred to revenue " for the year concerned. It will be observed that this amount of 6 per cent. has, on the present occasion, been entered as a deducted amount on the expenditure side. The effect on the balance is, of course, the same, but as the amount transferred might on occasions exceed the year's receipts from Compositions, it is suggested that the former procedure which will avoid this difficulty will be found to be the more convenient.

Among the liabilities in the Balance Sheet will appear the amount of the Fund at the end of the year, less the 6 per cent. transferred to the Revenue Account.

It is not proposed, and indeed it would be both difficult and wasteful, to keep separate assets in respect of this reserve, and the money representing the fund is to be found on the opposite side of the Balance Sheet in the General Fund Investments or the Cash Balance.

This method of treating the reserve does not preclude the Council from expending the whole of the receipts from Compositions in any year if the necessity should arise, but the fact that this had been done would be revealed by a corresponding adverse balance on the year's Revenue Account. So long, therefore, as there is a favourable balance on the year's Revenue Account the assets in the Balance Sheet will continue to grow *pari passu* with the growth of the Fund until ultimately a practically stationary condition will be achieved when the 6 per cent. that is transferred annually to current revenue approximates to the average annual receipts from Compositions.

It is somewhat difficult to estimate the ultimate size of the Fund, but if we assume level receipts in respect of Compositions of about £130 per annum, the fund would arrive at an approximately stationary state at about £2000.

As the amount of the liability of the Fund will be balanced by a corresponding amount of investments in the General Account, and as the dividends from these investments fall into revenue each year, it will be clear that in addition to the release of 6 per cent. of the Fund each year the Society will also in future have available, for general revenue, the interest on the Fund.

In addition to husbanding a portion of the receipts from Compositions and thereby leading eventually to an enhanced annual revenue, the scheme has the great practical advantage of smoothing the annual revenue of the Society and avoiding embarrassing fluctuations that arise from fortuitous variations in the numbers and duration of membership of Fellows who from year to year decide to compound for their annual subscriptions. T. W.

Gifts to the General Funds of the Society.

The John Lee Gift : In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell ; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856) : Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876) : R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2000 Consols.

The Lambert Bequest (1877) : C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The McClean Bequest (1905) : Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2000, free of legacy duty.

The Farrar Bequest (1906) : The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

The Parsons Gift (1922) : The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2500 War Stock (1929–47), in memory of his father, the 3rd Earl of Rosse, who made the 6-foot Reflector, and who died 1867 October 31.

The Grove-Hills Bequest (1922) : Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early Astronomical and Mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

The Grove-Hills Special Fund: In 1923 the then Treasurer, Col. Grove-Hills, collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. He aimed at securing £1800, and up to the present the total amount received from all sources (including dividends on the investments representing the fund) is £1905 6*s.* 8*d.*, of which £200 was transferred during 1923 to the General Fund to meet current expenditure, and £1480, 2*s.* 10*d.* has been invested, and is now represented by £525 War Stock 5 per cent. 1929–47, £419, 17*s.* 11*d.* Conversion Loan 4½ per cent. 1940–44, and £695, 16*s.* Conversion Loan 3½ per cent. 1961. In 1928 the Council resolved that the interest on the Special Fund should be regarded as part of the general income of the Society, and no longer funded.

	£	*s.*	*d.*		£	*s.*	*d.*
1929 Jan. 1. Cash Balance of Fund on Deposit ..	215	12	5	1929. Transfer to General Account	1	1	0
Donations in 1929	16	1	0	1929. Purchase of £525 5 per cent. War Stock, 1929–47	532	6	5
Redemption of National War Bond, 1929 ..	525	0	0	1929 Dec. 31. Cash Balance of Fund on Deposit ..	223	6	0
	£756	13	5		£756	13	5

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334, 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1929 Jan. 1. Balance of Fund	22	14	8	1929. Grants from Fund..	20	0	0
1929. Dividends, East Indian Railway ..	8	0	6	1928 Dec. 31. Balance of Fund	16	15	6
Income Tax, 1926 April–1929 April, refunded ..	6	0	4				
	£36	15	6		£36	15	6

The Turnor Fund and the Horrocks Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464, 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38, 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks: to this the Society added the sum of £55, 15*s.*, and the whole now stands in £103, 6*s.* East

Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

	£	s.	d.		£	s.	d.
1929 Jan. 1. Balance of Fund	3	3	5	1929. Purchase of Books..	17	12	11
1929. Dividends, East Indian Railway ..	13	12	10	1929 Dec. 31. Balance of Fund	9	7	11
Income Tax, 1926 April–1929 April, refunded ..	10	4	7				
	£27	0	10		£27	0	10

The Harry Watson Memorial Fund : In 1920 Mrs. Watson presented to the Society the sum of £300 as a memorial to her late husband Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the Library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s.* 2*d.* India 3½-per-cent. stock. In 1923 Mrs. Watson bequeathed a further sum of £958, 17*s.* 0*d.* to the Society, which now stands invested in £946, 6*s.* 11*d.* 5-per-cent. War Stock 1929–47. The Council resolved that these two sums should together constitute a Trust Fund, to be designated *The Harry Watson Memorial Fund*, to be used for the purchase and binding of books.

	£	s.	d.		£	s.	d.
1929 Jan. 1. Balance of Fund	44	7	4	1929. Purchase of Books..	28	13	6
1929. Dividends, India 3½ per cent.	19	0	0	Binding	71	7	9
Dividends, War Stock 5 per cent.	47	6	4	1929 Dec. 31. Balance of Fund	10	12	5
	£110	13	8		£110	13	8

The Hannah Jackson (née Gwilt) Fund : In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309, 18*s.* 6d. East Indian Railway 3-per-cent. Debenture Stock ; the interest to be given in medals or other awards in accordance with the terms of the Trust.

	£	s.	d.		£	s.	d.
1929 Jan. 1. Balance of Fund	13	1	7	Refund to General Account for Medals	12	12	6
Refund from General Account for Medals, 1928	12	12	6	1929 Dec. 31. Balance of Fund	26	2	1
1929. Dividends, East Indian Railway ..	7	8	10				
Income tax 1926 April–1929 April refunded.. ..	5	11	8				
	£38	14	7		£38	14	7

The George Darwin Lectureship Fund : In 1926 June, the then President, Dr. J. H. Jeans, presented to the Society the sum of £1000 for the endowment of an annual lectureship, to be called *The George*

Darwin Lectureship, the lecture to be on some subject of interest to astronomers, preference being given, in electing a lecturer, to one normally resident outside the British Isles.

This sum has been invested in £988, 3*s.* 3*d.* 5-per-cent. War Stock 1929–47, and the income will be annually applied to the purposes of the Trust in accordance with the terms of the Deed of Gift.

	£	*s.*	*d.*		£	*s.*	*d.*
1929. Jan. 1. Balance of Fund	24	14	1	1929 May. Lectureship Fee	49	8	2
1929. Dividends, War Stock 5 per cent.	49	8	2	1929 Dec. 31. Balance of Fund	24	14	1
	£74	2	3		£74	2	3

Celestial Photographs.

The following have been added to the list of Celestial Photographs reproduced by the Society for sale to the Fellows :—

R.A.S. Ref. No.

413. Eruptive Prominence, 1928 November 19 (Maximum height, 567,000 miles), Kodaikanal Observatory.

414. Solar Corona, 1929 May 9, Alor Star, Exp. 20 sec. (from 100^s to 120^s), 6-in. Refr., F.L. 45 ft., Jackson.

415. Solar Corona, 1929 May 9, Alor Star, Exp. 10 sec. (from 200^s to 210^s), 6-in. Refr., F.L. 45 ft., Jackson.

Publications of the Society.

During the past year the Society has published *Monthly Notices*, vol. lxxxix.; *Geophysical Supplements*, vol. ii., Nos. 3, 4; *Memoirs*, vol. lxiv. pt. 5, appendix to vol. lxv.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Arthur Berry.
Scriven Bolton.
*John Browning.
Ralph Hamilton Curtiss.
Walter Geoffrey Duffield.
Thomas Luther Evans.
John A. Ferguson.
John Granville Hawke.
Patrick Henry Hepburn.
George Innes.
Sir Otto Jaffé.
Bhawani Singh Bahadur of Jhalawar.
Sir George Knibbs.
Ernest F. J. Love.
Percy Alexander MacMahon.
Walter A. Mátos.
Willie Venner Merrifield.
S. Lynn Rhorer.
Herbert W. T. Roberts.
Alfred J. P. Shepherd.
Robert Norton Stevens.
Christopher Thwaites.
Worcester Reed Warner.
Associates :—Marie Henri Andoyer.
Georges Lecointe.

Arthur Berry, O.B.E., Vice-Provost of King's College, Cambridge, died on 1929 August 15 at Cambridge, following an operation. He was a son of Mr. Edward Berry of Croydon, and was first educated at the Whitgift Grammar School, University College School, and University College, London; he was then elected to a scholarship in King's College, Cambridge, where in 1885 he became senior wrangler, and in 1887 he won the second Smith's prize. He was elected to a Fellowship at King's College in 1886, and thereafter lived almost continuously at Cambridge. In 1902 July he married Miss Harriet Mary Johnson, who survived him only a few months. He was a University Extension lecturer for some years, and in 1924 was elected by the Fellows of King's as Vice-Provost. He is best known to astronomers by his excellent *Short History of Astronomy*, but he was also the author of many mathematical papers.

Berry was elected a Fellow of the Society on 1888 March 9. At the time of his death he was 66 years of age.

* Died 1925 December 15. Death not notified till 1929.

Scriven Bolton, though not often seen at the Society's meetings, was widely known by repute in astronomical circles, and his death on 1929 Christmas Day removes from our midst one whose contributions were of a somewhat unusual kind. That day will have melancholy associations for the Society, for it saw the passing of three other prominent Fellows also. Bolton, who was unmarried, lived with his widowed mother and sisters at Bramley, Leeds, where he was engaged in business as an oil merchant. But his chief interest was astronomy, and in a field adjoining his home he provided himself with a well-equipped observatory, containing, among other instruments, an 18-inch reflector. Here he carried out a programme of observations which, during the last seven years, comprised chiefly the determination of the periods and spectral types of new variable stars, especially those in the regions of the Pleiades and Hyades clusters. Reports of his work were sent to the Society from time to time, and appeared in the annual reports.

Bolton is best known, however, for his astronomical drawings. He was on the staff of *The Illustrated London News* for fifteen years, and to this paper, as well as *The Graphic*, *The Sphere*, *Le Journal Astronomique de France*, and several American papers, he frequently contributed sketches illustrative of the objects, apparatus, etc., with which astronomers are concerned. He was a very skilful draughtsman, and received many awards for his work. He obtained a gold medal for his exhibit in the Science section of the Franco-British Exhibition in 1908, and a diploma for drawings of astronomical subjects at the Japan-British Exhibition, 1910. The Astronomical Society of Barcelona also presented him with a certificate. He was, in addition, a painter of some skill in pastel, and produced several musical works for private performance.

At the beginning of his last illness he had just completed the construction of a large reflector for his observatory. It was probably on account of the interruption of his observations by this work that he did not send his customary report to the Society during the last two years. He died in his early forties after an illness of three weeks. He had been a Fellow since 1905 May 12.

John Browning, whose death, though occurring in 1925, has only during the past year come to the notice of the Society, was one of the oldest of our Fellows. Among his few seniors in membership was Robert Norton Stevens, elected a few months earlier (on 1865 January 13), who died on 1929 October 29, and of whose career we have unfortunately been unable to obtain particulars. Browning was a well-known figure in the scientific world 50 years ago, his skill in the construction of instruments, not so widely used then as now, bringing him into intimate relations with many of the leading scientific workers of the day. He contributed many papers to the *Monthly Notices*, notably a series on changes in the colour of Jupiter's equatorial belt, about 1870.

Browning appears to have been born early in 1835 in London, where his father, Mr. Spencer Browning, conducted a nautical instrument-

maker's business at 111 The Minories. The business was established as far back as 1760, and it is suggested that Browning's may have been the actual shop which Dickens had in mind in his description of the establishment of Solomon Gills, the ship's instrument-maker, in *Dombey and Son*. It would, at any rate, have been of the same type, and was certainly provided with one of the "little timber midshipmen in obsolete naval uniforms, eternally employed outside the shop doors of nautical instrument-makers in taking observations of the hackney coaches." There was also a "Captains' Room," of which sailors made frequent use for a quiet gossip over their sherry. An old habitué with a wooden arm and a hook in it, whose memory has not yet faded away, might well have been the prototype of Captain Cuttle.

Browning was originally intended for the medical profession, and, with that end in view, entered Guy's Hospital and passed the necessary examinations. A breakdown in health interfered with this plan, however, and resulted in his joining his father's business. Here he encountered an initial difficulty arising from the growth of shipbuilding on the Mersey and Clyde and the establishment of instrument-makers' shops in those districts. Seeing that effective competition was hopeless, Browning changed the character of the business and entered with a will into the agreeable task of designing and constructing instruments of precision for scientific work. Early in the seventies the business (which was then a flourishing concern, employing some 70 men besides "bunting girls," or flag makers, and odd labourers) was transferred to 63 Strand, where it rapidly gained the patronage of workers in various departments of science. The factory in The Minories was shortly afterwards destroyed to make room for railway extension.

Practical optics was the chief interest of Browning's life, and he soon began to develop his business on the ophthalmic side. Here his medical training stood him in good stead and he gained wide repute among ophthalmic surgeons in London. The making of spectacles was an art greatly in need of reform when Browning turned his attention to it. At a time when the advantages of reflecting telescopes were not fully realised he did much pioneer work in bringing those of his own construction to the notice of astronomers, and one of the later editions of his book, *A Plea for Reflectors* (first published in 1867), on the shelves of our library, contains numerous testimonials from those who had used his instruments and gives an interesting insight into his methods of popularising the subjects with which he was concerned. But perhaps his foremost interest was the spectroscope, of which for many years he was the leading English maker. His book, *How to Work with the Spectroscope*, also in our library, was well known to an earlier generation of spectroscopists, and Browning's pioneer constructive work undoubtedly did much to raise the spectroscope from a somewhat neglected chemical accessory to its present position as one of the most important instruments of physical research. Browning's spectroscopes were the best obtainable in England in their day, and much early work of the highest order was done with them. He was fortunate in this branch of his business to acquire the services of Mr. Adam Hilger, who, on coming

from Paris to London with his brother at the outbreak of the Franco-Prussian War in 1870, was employed by Browning as his foreman. Hilger's great skill in this work was doubtless an important factor in the excellence of Browning's spectroscopes, but Browning's own able and conscientious craftsmanship was of very high quality. His zeal for perfection sometimes had untoward results. It was, for instance, partly on account of his reluctance to part with a spectroscope until it had "performed" to his satisfaction that Lockyer was not the first observer to see a prominence on the uneclipsed Sun. His unwitting share in this misfortune was always a source of regret to Browning, and he lost no opportunity for many years afterwards of pointing out to all and sundry that he was largely responsible for the delay. One of his favourite ideas was the importance, from the meteorological point of view, of the "rain-band" in the solar spectrum, and it is interesting to know that this has been realised afresh in recent times.

A former associate of Browning, Mr. W. Woodward, now living at Walthamstow, has kindly supplied some interesting reminiscences from which the following paragraphs are taken. Mr. Woodward joined the firm about 1869, and remained until the middle seventies, when he left with Mr. Adam Hilger, who then set up in business for himself. Writing of this period, during which the transfer from The Minories to the Strand took place, Mr. Woodward says :—

"Astronomy became his hobby, and at his home near Sevenoaks on fine nights he frequently had one of the staff there all night observing. We used to say he thought more of a piece of the Moon's surface being called 'Browning's Land' than of success in business. He put up the first electric light in London when we illuminated the Guildhall for the banquet to the Shah of Persia on his visit to Queen Victoria. We had a light outside each window, as they had to be run with Bunsen cells, the fumes being impossible inside. Each light cost £3 an hour to run.

"The properties of the telephone and the phonograph were well known long before they became a practical proposition, and we made frantic efforts to 'get there' first. We had a man with a stentorian voice who used to go on the roof of 63 Strand and shout, 'Hullo, I am here!'; and Browning below, with the receiver glued to his ear, would say, 'I can hear him!' So could we; his voice resounded through the building! Then, again, with the phonograph; we coated the cylinder with every conceivable foil we could think of—lead, tin, brass, copper, canvas, silk, etc., etc., with no success. But to hear the reproduction of Miss Browning's voice after she had sung 'The Last Rose of Summer' on to our tin-foil effort was something to be remembered. It remained for Edison to hit upon the happy thought of hardening the wax itself after he had asked all the world to try and solve the problem.

"Mr. Browning was kind and considerate for his workpeople and always ready to help in distress. We had long hours in The Minories —from 6 a.m. to 8 p.m. at first—but they were a contented crowd. There were no outside diversions except skittles and beer, which was very cheap, so Mr. Browning started a tonic sol-fa class and encouraged the men to sing at their work, which they did. 'Soh, doh, doh, me, doh,

doh, la ' would start in various quarters, until we had a chorus in full blast. Adam Hilger, who was musical and often played the zither in public, said he ' sufreed martreedum ! ' "

Browning was always more drawn to scientific research than to industrial development, and in later years his business declined considerably. About 25 years ago he retired and went to live at Cheltenham, having been given but a short lease of life by his medical advisers. He recovered, however, and was able to take a leading part in the scientific and educational life of the town. At the end of the year 1925, at the advanced age of 90 years, and after more than 60 years' Fellowship of the Society, he passed away. He is survived by his widow and only daughter, who is the chief librarian at Bradford Library.

Ralph Hamilton Curtiss was born on 1880 February 8 at Derby, Conn. He graduated from the University of California, receiving the degree of Doctor of Philosophy in 1905. In 1901 he was a member of the Lick Observatory expedition to Sumatra ; he was connected with the Lick Observatory as Fellow until 1905, when he joined the staff of the Allegheny Observatory as Astronomer. In 1907 he went to Michigan University as Assistant Professor. Four years later he was made Assistant Director of the Detroit Observatory, Ann Arbor, under W. J. Hussey, and in 1918 he became a full professor. He succeeded Hussey as Director of the Observatory on the latter's death in 1927. From 1911 onwards Curtiss was responsible for the whole of the spectroscopic work of the Observatory, and the one-prism and two-prism spectrographs used in conjunction with the $37\frac{1}{2}$-inch reflector were designed by him and built under his direction at the Observatory. He also designed the measuring engine. This work is described in vol. i. of the *Pub. Michigan Obs.* (1912). He was greatly interested in the photographic reproduction of stellar spectra ; all of the five series of spectrograms in vol. ii. of the *Publications* were prepared by Curtiss, as there described.

Curtiss was at home in many astronomical fields, but his main work lay in the study of spectroscopic binaries and of early type stars showing bright lines. He combined observational skill, accuracy, and care in reductions with a critical faculty for his own and others' material in a way that was probably unsurpassed. His contributions are to be found mainly in six memoirs on stars of class B showing emission lines published in the Allegheny publications and in the three volumes of the Michigan publications. These include a study of the spectrum of β Lyræ, a study of Cepheid characteristics, and a prolonged study of the spectra of δ and ϵ Orionis and of γ Cassiopeiæ. It is worth remarking at the present day that Curtiss concluded in 1912 that the sharp lines of H and K in δ and ϵ Orionis were definitely non-oscillatory, and that following Hartmann's hypothesis the calcium cloud had a radial velocity of 14 km.sec.$^{-1}$ relative to the Sun. Curtiss realised fully the need for quantitative measures of line-intensities as an aid to the elucidation of physical conditions in stellar atmospheres, and

studied for this purpose the widths of the hydrogen and metallic emission lines in spectra of type B. He almost invariably concluded his rigorous discussion of data with a more speculative discussion of the physical conditions in the object observed, and his sixth memoir contains a general discussion of the evolutionary position of the bright-line B stars as products either of dark nebulæ, bright nebulæ, or planetary nebulæ. Though non-mathematical, Curtiss's treatment of these questions was always in the highest degree stimulating and suggestive.

At the time of his death Curtiss had practically completed for the press two more volumes of the Michigan publications, comprising work done under his direction and including in particular a spectrophotometric study of the variation of the bright and dark lines in β Lyræ. He was also engaged on a substantial general account of stellar spectra and their classification for the *Handbuch der Astrophysik*; this, too, was almost ready for publication. Since his appointment as director Curtiss had worked constantly for a new and larger observatory, and a fortnight before his death the University acquired a site of 200 acres for the purpose.

In 1929 December Curtiss had a severe attack of pleurisy, from which he had apparently recovered when he succumbed suddenly to embolism of the heart on Christmas Day. He leaves a widow, Marie Louise (*née* Welton), whom he married in 1920.

His death leaves a great gap in the ranks of astronomers, and it is a tragedy for astrophysics that he was not permitted to live through what should have been his prime. Work such as Curtiss's is the fine treasure of true science. But beyond his own contributions he had the power of inspiring his students and assistants with the zest for arduous investigations, and of communicating to them the power and assiduity to bring them to positive conclusions. It is not easy to convey the quiet, unaggressive, attractive yet confident manner in which he faced his problems and the astronomical problems of the day. Curtiss was a true leader of an observatory—a scientist of vision, a friend to his staff, and a welcoming host to visiting astronomers. Moreover, he took a great part in interesting the general public and prominent citizens of Detroit in astronomical matters. He was much beloved.

He was elected a Fellow of the Society on 1927 May 13.

E. A. M.

Walter Geoffrey Duffield was the son of the late Mr. W. Duffield of Adelaide, and a grandson of Senator Walter Duffield, one of the first members of the South Australian Parliament. He was educated in Adelaide and graduated at the University of Adelaide in 1900. He afterwards came to Cambridge and passed out in the Mechanical Sciences Tripos in 1903. Later he became an honorary research Fellow of the University of Manchester, where he received the Degree of D.Sc. in 1908. His principal work was the effect of pressure upon arc spectra, and he communicated four memoirs on this subject to the *Philosophical Transactions of the Royal Society* between the years 1907 and 1915. In 1906 and

1907 he also held a Mackinnon Studentship awarded by the Royal Society. In 1911 Duffield was appointed Professor of Physics at the University College of Reading, a position he held until 1923. During these years his researches included the discovery of a minute repulsion between the poles of the carbon arc, and an attempt to determine the value of gravity over the ocean during a voyage to Australia and back in 1914 in connection with the visit of the British Association. His results for the last named were published in the *Proceedings of the Royal Society*, vol. 92. An account of his preparations for this work and the difficulties he encountered were given also in the British Association Report for 1915, p. 18. The main object of the research was to obtain results bearing on the theory of isostasy. Duffield had hoped to attack the problem again on a ship whose destination and speed were under control of the experimenter, but as this was not possible he decided to carry out further research on the SS. *Anchises* and *Nestor* on the Cape route between Great Britain and Australia in 1922–23. Many important observations were obtained, but Duffield did not consider that a final solution of the problem had been reached. A paper on " The Problem of Measuring Gravity at Sea," embodying the results of this voyage, was contributed by him to the *Geophysical Supplement to M.N.R.A.S.*, vol. 1, No. 5, 1924.

In 1908 a committee was appointed by the British Association under the chairmanship of Sir David Gill to forward the scheme of establishing a solar observatory in Australia, and Duffield was chosen as secretary. He made great efforts to carry his fellow Australians with him in this project, and in 1914 the committee was received by the Prime Minister of Australia and was assured by him of favourable consideration as far as the outbreak of war and the prevailing uncertainty would permit. The decision to erect a solar observatory at Canberra was not reached until 1923, and Duffield was persuaded to accept the post of first Director, although he himself did not consider his physical research to be sufficiently connected with astronomy and astrophysics for the post. When he died on 1929 August 1, the equipment of the Observatory was by no means complete, and his premature death in the midst of all the preliminary work was a great blow to the staff and to his many friends in this country and elsewhere. A first Memoir from the Observatory, on " The Luminosity of the Night Sky " (continuing an investigation originated by the present Lord Rayleigh), in which special attention is given to the auroral green radiation, was issued in the spring of 1929, and a large number of stellar spectra in the southern hemisphere of the sky have been photographed with the objective prism refractor for the spectral determination of stellar parallaxes.

Duffield always suffered from asthma, and the strain imposed on him by this complaint was at times very great. He was buried near the summit of Mount Stromlo, within view of the observatory, at a site specially consecrated by the Bishop of Goulborn, and the funeral was attended by the Ministers of Defence and of Home Affairs and other government officials, and by a large concourse of friends.

Duffield was elected a Fellow of the Society on 1908 January 10 and took an active interest in its proceedings.

His sympathetic and kindly nature will always be remembered by those who were privileged to know him. He leaves a widow (formerly Miss Doris Boult of Adelaide) and three children.

J. H. R.

Thomas Luther Evans died on 1929 February 23 at his home at Bristol at the age of 76. He was born at Aberayron on 1852 September 2, and for practically the whole of his life was associated with Bristol shipping. He began his career as shipmaster as far back as 1877, and in 1879 was in command of the S.S. *New York City*, being promoted to the S.S. *Gloucester City* in 1881, when he resigned to take command of the S.S. *Carlton Tower*, one of the Tower Line, London. Trading to India for a period of three years, he undertook the supervision of the construction of two steamships for the North Atlantic Steamship Company. He then became Marine Superintendent of that company, and after a period of ten years he resigned and was elected managing director of the Donald Steamship Company, Bristol. For fourteen years he held this position, and supervised the whole of their fleet during construction.

For many years he was a member of the Institute of Naval Architects and a Younger Brother of Trinity House, London. He also served on the local Marine Board and Sailors' Home Committee. He was a member of Bristol Steamship Owners' Association, Commercial Rooms, and Constitutional Club. During the War he managed two ships for the Admiralty.

He was elected a Fellow of the Society on 1921 January 14.

John Granville Hawke, although only elected a Fellow of the Society on 1927 June 10, acquired while a boy at school an interest in astronomy which was maintained throughout his life. He was for many years a member of the British Astronomical Association, and was a regular attendant at the meetings of that body. Born at Barnet on 1877 January 28, the eldest son of Mr. John Hawke, he was educated at a private school at the Old Hall, Wellington, Salop. On leaving school he was articled to a firm of solicitors in London, and remained with them until the outbreak of war in 1914. Not being strong enough for the Army, he took a temporary managing clerkship with another firm while their regular clerk served with the forces. On the latter's return Hawke moved to the Solicitors' Department of the Inland Revenue at Somerset House, at first as professional clerk, but afterwards, in 1927, he was promoted to an assistant chief clerkship and became an established Civil Servant. The photograph of the Society's early premises in Somerset House, which now hangs in the Assistant Secretary's office, was presented by him to the Society. In the year of his election as a Fellow he bought a piece of land at New Barnet close to his house, and erected an observatory to accommodate his Calver equatorial reflector of $9\frac{1}{4}$-inch aperture, and there he spent all his spare time in

astronomical pursuits. He was particularly interested in the planets, especially Jupiter, but concerned himself with other departments of astronomy also, making frequent use of a Zöllner star spectroscope which he possessed. He was fortunate enough to obtain a good view of the total eclipse of the Sun of 1927 June at Southport. Hawke was unmarried and lived at the time of his death at his father's house in New Barnet. He died on 1929 July 30, after a serious operation, at the age of 52.

Patrick Henry Hepburn. Of these biographies that appear year by year in the volumes of the Society, some are records of men who have died after years of useful work, and sorrow is tempered by the thought that the number of those years makes the loss inevitable. Others are of those whose connection with our science and Society is but slight, and lack of personal knowledge forbids more than conventional regret. Neither description is applicable to the notice now being written, for its subject was one well known to those who meet in astronomical association, to whom death has come in the prime of life, bringing a loss to the science not inconsiderable.

Hepburn came into the astronomical world about the year 1911, though his personal interest in the science began much earlier, for he observed the heavens with a small telescope in his boyhood, went with the British Astronomical Association expedition to Vadsö in 1896 to observe the Total Solar Eclipse in August of that year, saw the eclipse of 1900 from Spain, and in 1905 August occupied a station independently of any organised expedition at Alcala de Chisvert, 2000 feet above sea-level, overlooking the Mediterranean, from which he had a superb view of the circumstances attending the eclipse, and brought home some good photographs. But the above statement is justified by the facts that he joined the Royal Astronomical Society in 1911 April, and took up office in the British Astronomical Association as Director of the Saturn section in October of the same year, having in the previous January contributed his first paper to the *Journal* of that organisation. This paper was a discussion of the reasons for certain peculiarities of illumination of the moon's disc when in eclipse, and was followed in 1912 March by another in the same publication that was equally characteristic of Hepburn. He always deprecated the idea that he was a mathematician, but he had a good knowledge of the elements and a logical mind, and in this second paper he analysed, or reconstructed from first principles, the apparently complicated and puzzling diagram of a solar eclipse (1912 April 16) given in the *Nautical Almanac*. He enjoyed nothing better than using his mental capacity to elucidate the cause of some astronomical fact. It has been said that Saturn was specially the subject of his investigation, and two illustrations relating to this planet may be mentioned. In drawings made when the Rings are most widely open, Cassini's division is usually shown as being visible beyond the polar limb of the Ball, which, from geometrical considerations, would not happen if the dimensions of the planet were as given by the measures of recent years. This led Hepburn to have measures made of

Saturn and his Rings as shown on a photograph taken by Professor Barnard with the 60-inch reflector at Mount Wilson, a copy of which is in the possession of the Society. The results of these measurements compared with other measures are given in a paper in the *Monthly Notices* of 1914 June, and in the course of this investigation he had the readiness to notice an increase of brightness in the regions where the Ring is superposed on the Ball, which led him to infer that Ring A is transparent. The conclusion was contested, and views on the subject will be found in vol. xxv. of the *B.A.A. Journal.* For the second illustration we pass to the years 1920–1921, when the line of nodes of the ring-plane crossed the orbit of the earth, and that plane passed through the earth three times. In the first of a series of papers (*B.A.A.J.*, 1920 February) Hepburn explained these occurrences in easily understood geometry, and in later items of the series, and in his report of the work of the section, dealt with the possible appearance of the ring-system compared with the actual observations, renewing his consideration of possible transparency of the Ring. It may be mentioned that he contributed the largest share of the observations made by the section during this period, observing generally with a 12½-inch reflector, formerly belonging to Mr. Arthur Cottam, F.R.A.S., which he had set up in his garden at Hampstead, but sometimes using the Greenwich 28-inch refractor which was put at his occasional disposal by the Astronomer Royal. That he would come from North London to Greenwich, observe from midnight until dawn, and then go to town for his daily professional duties, seems to be a striking tribute to his energy. Hepburn was President of the British Astronomical Association for the usual period of two years, from 1920–1922 October. He was a specially capable and painstaking occupant of the Chair, and his two Presidential Addresses, the first a valuable analysis of contemporary knowledge of stellar physics, the second a survey of astronomical work in the past as compared with that of the present day, are brilliant expositions and remarkable examples of his thoroughness in all he undertook and his aptness in choice of subjects.

To complete the record of his eclipse enterprises, it is to be added that on the occasion of the central eclipse of 1912 April 17, which was for the most part annular, he went to Chartres, a short distance to the south-west of Paris, and obtained a photograph of the sun at the central phase, the annulus being broken by black markings. In 1914 he went as volunteer observer with the official expedition from Greenwich to Minsk in Russia, where moderately fine weather prevailed at the time of totality, and gave efficient and wanted help. In 1927, when totality was visible from England, he made his observations and took photographs from an aeroplane, in company with Dr. G. Merton, and as an example of his not infrequent efforts for the general good, it may be added that it was largely due to him that on this occasion the seconds of the Greenwich clock were broadcast at the time of the eclipse.

Writing the last paragraph brings to mind Hepburn's adventurous services in the Great War. Shortly after its outbreak, though past military age, he joined the R.N.A.S. (afterwards the R.A.F.) as a balloonist, and had service in German East Africa, round the British coast,

and at Gibraltar and Malta. On an occasion in England when making some experiments or repairs to a captive balloon at Roehampton, the vessel, caught in a sudden storm, overturned, but righted itself, and Hepburn was carried away into Norfolk. Having barely escaped with his life, he treated the matter with apparent unconcern, which was very characteristic. That in a period of leisure at Gibraltar, having made the acquaintance of the local padre, he began the study of Hebrew with some effect, is a striking example of his versatility.

Patrick Hepburn was descended from a family engaged in the leather and skin trades, and the name survives as part of the title of firms now engaged in the business ; but his father, the late James S. Hepburn, was a lawyer, and at the time of his death the subject of this notice was sole principal of Hepburn, Son & Cutcliffe, Solicitors, of Cheapside. He was born on 1873 February 4, went to school at Charterhouse, and Amersham Hall School near Reading, and then entered his father's office. He qualified as a solicitor in 1899 and took the degree of LL.B. at London University, with honours, in 1899. Hepburn had many interests in life. Hereditary association brought him into connection with the Curriers' Company, of which he had been Clerk for several years immediately preceding his death, and Master in 1913. He made a study of the architecture of Saxon and Norman churches, and had a large collection of lantern-slides made by himself, which included a series, believed to be unique, of the churches in the neighbourhood of Caen. The Hampstead Scientific Society owes much to him, for when it acquired, about 1909, an 8-inch reflecting telescope, which was housed in an Observatory on Hampstead Heath for semi-public use, Hepburn took it into his care and faithfully discharged the duties that this involved.

To summarise his personality, it might be said that he was apt and anxious to acquire knowledge ; he was strong and athletic, energetic in mind and body, courageous even to recklessness, but withal, modest and unassuming. Valentine Ball (son of Sir Robert), an old friend who at one time shared a home with Hepburn, relates an amusing incident. One summer evening Hepburn, who was an enthusiastic and tireless bicyclist, went for a ride in Hertfordshire with the intention of returning that night. But he did not appear until the next evening, and to Ball's inquiry what had happened, answered, " Oh, I got as far as Ware, and as it was fine, I rode on to York and came back this afternoon by train." He developed of late a passion for walking, and at holiday times, or at such times as his practice allowed, would, accompanied sometimes by one of his sons, make a hasty train journey north and walk among the Cumberland hills. He did this, unaccompanied, last December, and left his hotel at Grasmere about one o'clock on Christmas Day to walk to Borrowdale, though advised of possible danger because of the time and the weather. As the result of some accident, the exact course of which has not been fully traced, he was found drowned in a stream in Langstrath Valley on Thursday, December 26, the date of his death being presumed to be December 25. He was buried in Rosthwaite Churchyard.

Hepburn leaves a widow and three sons. Mrs. Hepburn, formerly Miss Harper, whom he married in 1906, was an Australian lady, who has published some volumes of verse under the name of Anna Wickham.

He was elected a Fellow of the Society on 1911 April 12, served on the Council from 1922 to 1928, and as Treasurer during the year 1927–1928.

H. P. H.

George Innes was a dispensing and photographic chemist who engaged also in optical work. At the time of his death, which occurred suddenly on 1929 May 3, when he was 72 years of age, he was residing at Edinburgh. He was born at Temple, Midlothian, in 1857, and became a Fellow of the Society on 1907 January 11. He was greatly interested in astronomy, and although unable to take any active part in current astronomical work he spent much of his spare time in study and observation, especially in his earlier days. Innes, whose widow survives him, had no children.

Sir Otto Jaffé, who was best known for his services to the city of Belfast, died on 1929 April 29 in his eighty-third year. He was born at Hamburg on 1846 August 13, and received his education in Belfast (where his father, Mr. David Joseph Jaffé, was engaged in business) and Switzerland. He afterwards entered his father's business, the firm of Jaffé Brothers, which was extensively engaged in the linen and yarn trade, and did much to develop the north of Ireland linen industry by exporting largely to the Continent. His prominent public work began in 1892, when he entered the Belfast Corporation. In 1899 and 1904 he was Lord Mayor and in 1901 High Sheriff of that city, and his business experience and capacity were of much service to the Corporation. He was deeply interested in all progressive and philanthropic movements, particularly in connection with the Jewish congregation. He founded an elementary school largely for Jewish children, and was an active member of the committee whose efforts to have the Public Libraries Act extended to Belfast led to the establishment of the Free Library. Hospital work and the Harbour Commission also benefited greatly from his active interest.

Education and research claimed a great deal of Jaffé's attention, a gift of 30 milligrams of radium to the old Queen's College (now the Queen's University) of Belfast in 1901 being used in part for research in the process of linen manufacture. He was chairman of the Technical Education Committee of the Belfast Corporation, and served on the Board of Technical Instruction, Dublin. The Belfast Natural History and Philosophical Society and Society for the Extension of University Teaching numbered him among their vice-presidents, and he was one of the founders of, and chief contributors to, the fund for the better equipment of Queen's College, Belfast. For several years he was chairman of the Executive Committee of that institution, and in 1905, by a gift of £3000 in addition to a previous donation of £1000, he secured the gift of £20,000 which Sir Donald Currie had offered if an equal sum

were raised otherwise. He was knighted in 1900, following his first Lord Mayoralty, and his public services were recognised by the Royal University of Ireland in 1907 by the bestowal of the degree of LL.D.

His connection with astronomy, though subordinate to the interests just outlined, was by no means negligible. He was elected a Fellow of the Society on 1892 May 13, and in his earlier days he started to make a telescope which he found it necessary to engage professional assistance to complete. With this instrument he made many observations for his own edification, and he was always keenly interested in the wonders of the skies. Through the kindness of his sons, Mr. A. and Mr. W. Jaffé, the telescope has lately been presented to the University of London Observatory.

Jaffé was an accomplished linguist and generously offered his services as interpreter to the Society at more than one international gathering.

He leaves a widow (formerly Miss Paula Hertz), with whom he celebrated their golden wedding in March last, and two sons.

Sir Bhawani Singh Bahadur, K.C.S.I., Maharaj Rana of the Rajput State of Jhalawar, was one of those enlightened rulers who, in practice as well as theory, regard their high office as a responsibility rather than a privilege. Intensely interested himself in intellectual pursuits covering a wide field, one of his chief concerns was the dissemination of western knowledge and culture among his subjects. He was born on 1874 September 4, a descendant of the first Faujdar or Commander of Troops of Kotah in Jhalawar, and was educated at the Mayo College, Ajmere. He came to office in difficult circumstances, his predecessor, Zalim Singh, having been deposed in 1896 after repeated admonitions and temporary suspensions of power by the British Government for gross mal-administration and self-indulgence. The State was reconstituted, and certain portions, always claimed by Kotah, were transferred thereto. Bhawani Singh was selected from among the collateral relatives to be the new ruler, and was duly invested with powers in February 1899. His anxieties were increased by the occurrence of a terrible famine in the following year, but the young ruler rose to the occasion and took over the work of relief in person, dealing very effectively with the difficult situation. He immediately initiated a systematic policy of reform and reconstruction, and had the good fortune to be assisted by capable officers.

His first visit to Europe took place in 1904, and his experiences on that occasion were recorded in a diary which formed the basis of his book *Travel Pictures*, published in 1912, "primarily for the benefit of my people in Jhalawar, whose ideas of European civilisation are of the vaguest." The book is an interesting example of the wide curiosity and power of observation which characterised him throughout his life. Thereafter he frequently visited the western world, and in 1925 he made a journey round the globe, taking full advantage of the intellectual amenities afforded by the different countries which he

visited. After the death of his wife, in 1918, he spent the greater part of his time in this country with his foreign minister, Pundit Shyam Shankar, returning to India only at the call of administrative duties, and finally owing to the financial strain involved in residence abroad. When, in 1920, his son, Kumar Rajendra Singh, who now succeeds him, came to Oxford as an undergraduate, he seized the opportunity of systematising his knowledge, and was himself also admitted by the University on special terms to an undergraduate course, which unfortunately his imperative return to India precluded him from completing. He became a well-known figure in intellectual circles in England, and his charm of manner, ready hospitality, and eagerness to help to the best of his power in any project for the advancement of knowledge and culture endeared him to a wide circle of friends. He died suddenly on board the steamer "Ranpura" on his way from Bombay to Europe in 1929 April.

The many reforms which he introduced in his State included the grant of urban municipal self-government and the creation of a bicameral legislature on a broad electoral basis such as few States have approached. His palace, built to his own designs, combined Indian architecture with the latest western equipment, and contained the finest privately-owned library in Rajputana and one of the best in India. Many years ago he established a society in Jhalawar for translating and studying the works of Shakespeare. On the outbreak of war he not only gave much financial assistance to the allied cause, but characteristically organised weekly lectures to his people designed to spread correct information and to be an antidote to the prevailing tendency to alarming rumour. In recognition of his war service his hereditary salute was raised from eleven to fifteen guns. By every means in his power, and at every opportunity, he sought to promote cordial relations between Britain and India.

Among his very wide interests, astronomy always occupied a prominent place. So far back as 1901 he was sufficiently familiar with the face of the sky to be an independent discoverer of Nova Persei, though he was anticipated by Dr. Anderson in this matter. When, soon after the termination of the war, he came to live mainly in England, he availed himself of the opportunity of getting into close touch with astronomers, becoming, for example, as well as a Fellow of the Society, a member of the Norman Lockyer Observatory Corporation, to which he subscribed liberally. He arranged for private lessons in astronomy, which he took daily so far as his many duties and other engagements allowed, and was never ashamed to acknowledge ignorance of even elementary matters if thereby he could clarify his ideas. Indeed, the mental characteristic which most impressed his tutor was his intellectual humility and anxiety to understand fundamental principles thoroughly before turning to the superficially more interesting cosmogonical speculations so tempting to the dilettante. Whenever a difficult point was grasped, he sought for some illustration by which he might bring it home to the minds of his people. Nor did he hesitate to seek self-improvement in other respects. Although he spoke English almost

perfectly he would beg to be corrected in any misuse or mispronunciation of English words, and would accept interruption for such a purpose with gratitude, repeating to himself the correct form until he had mastered it. This remarkable quality is not often met with in such a degree, and the influence which it gave him in promoting the welfare of his people will not easily be replaced.

He was elected a Fellow of the Society on 1912 December 13.

Sir George Knibbs, C.M.G., eminent as a statistician and economist, was born at Sydney, Australia, on 1858 June 13. He began his career as a surveyor and civil engineer, and from 1877 to 1889 was on the staff of the Trigonometrical and General Survey of New South Wales, afterwards becoming President for four years of the New South Wales Institution of Surveyors. Following this he became an independent lecturer in the Department of Engineering, and subsequently an acting Professor of Physics in Sydney University. He retained the last-named post until 1906, when he became Commonwealth Statistician. In this capacity he brought out the *Commonwealth Year Book*, which, on account of its comprehensiveness and accuracy, is regarded as one of the best statistical publications in the world. He also devised the mathematical formulæ on which the Commonwealth land and income taxes are assessed. In 1921 he was appointed Director of the Commonwealth Institute of Science and Industry, and he remained in this post until his retirement from public life in 1926. In recognition of his services to Australia he was created C.M.G. in 1911 and knighted in 1923.

Knibbs took a practical interest in many departments of knowledge and research, his wide acquaintance with foreign languages making him a valuable member of the numerous international congresses which he attended, often as a delegate of the Australian Government. In 1897–98 he was President of the New South Wales section of the British Astronomical Association. He was President of the Royal Society of New South Wales in 1898–99, and for nine years was honorary secretary of that body. In 1923–24 he became President of the Australasian Association for the Advancement of Science, and he served as Royal Commissioner for all branches of education for New South Wales from 1902 to 1906; for insurance for Federated Australia from 1909 to 1910; and for trade and industry during the War from 1914 to 1915.

Among other of his many activities might be mentioned his services as consulting member of the committee for munitions of war during the late struggle, and his chairmanship of the Royal Commission on the taxation of ground leaseholds in 1918–19. In 1923 he was Vice-President of the Pan-Pacific Congress.

Knibbs contributed to the scientific press numerous monographs on pure mathematics, geodesy, and geodetic instruments as well as larger works. Among the latter are *The Mathematical Theory of Population*, *The Census of Wealth*, and (published shortly before his death) *The Shadow of the World's Future*. The last-named book is a study of the relation of the growth of world population to food pro-

duction and migration influences, and contains a warning of the danger of over-population inherent in current national policies. He wrote also a number of poems, his publications including "Voices of the North" and "Echoes of Hellas."

He died on 1929 March 30, in his seventy-first year. His Fellowship of the Society dated from 1896 January 10.

Ernest Frederick John Love, who died on 1929 March 9 at his home in Melbourne after a Fellowship of the Society of more than 32 years, was the eldest son of the late Dr. J. H. Love of Wolverhampton and a brother of Professor A. E. H. Love of Oxford. He was born at Weston-super-Mare on 1861 October 31, and received his early education at the Wolverhampton Grammar School, proceeding later to St. John's College, Cambridge. He acted for a short time as lecturer on Physics at Birmingham University, and then migrated to Australia, where he held the post of senior lecturer in Natural Philosophy at the University of Melbourne continuously from 1888 up to his resignation in 1927. His work was chiefly concerned with astronomy, thermodynamics, geophysics, and acoustics, and in the latter subject he was able to give valuable help in the construction of buildings in the country of his adoption. In particular he was consulted by the architects of the Melbourne Town Hall, and the building recently erected owes much of its success acoustically to his advice. Cobourg Town Hall, Victoria, which had to be considerably altered owing to defects in acoustical properties, is also greatly indebted to the part he took in its remodelling. Geodesy claimed much of his attention, and at the time of his death he was secretary of the Geodesy Committee of the Australian National Research Council. In 1893 he published an account of the measurement of gravity at Australian stations. He was a life member of the Royal Society of Victoria from 1889 onwards, and contributed many valuable papers to the proceedings of that body. From 1899 to 1903 he was President of the Victoria branch of the British Astronomical Association, and in 1907 he was elected President of Section A of the Australasian Association for the Advancement of Science. Love never married, and during his first seven years in Australia he resided in Queen's College, Melbourne University, of which he was elected a Fellow. In 1896, however, his sister went out to Australia, and he then left the college to reside with her.

In Major P. A. MacMahon the Society loses one of that series of distinguished pure mathematicians who, without being themselves astronomers, have shown devoted attachment to the Society and have served long on its Council and been chosen as Presidents. Arthur Cayley was President 1872–74 and was editor of the Society's publications 1860–82, except during the two years of his Presidency. He was on the Council 1858–93 and a very regular attendant. J. W. L. Glaisher was President twice, 1886–88 and 1901–3, and served on the Council continuously 1874–1928. The older Fellows will remember also Sir James Cockle, who was a Fellow from 1854–94 and served on the Council

1888–92. Major MacMahon became a Fellow on 1897 January 8, and was elected on Council almost at once [on 1898 February 11. Of the twenty-one forming that Council only four now survive]. He remained on Council, serving several terms as Vice-President, until 1911, when his name disappeared from the list for a few years, to return as President in 1917–18. After three more years' service he retired, partly for reasons of failing health. But this brief statement of facts is sufficient to show his attachment to the Society and the esteem in which it held him.

Percy Alexander MacMahon was born at Malta, 1854 September 26, the second son of Brigadier-General P. W. MacMahon. He was sent to Cheltenham College, joined the Royal Artillery from the R.M.A. Woolwich in 1872, and saw some service in India. Ten years later he returned to the Royal Military Academy as Instructor in Mathematics, and in 1890 he was appointed Professor of Physics at the Ordnance College, holding that post until 1897. He retired from the Army in 1898. From 1906 to 1920 he was Deputy Warden of the Standards, under the Board of Trade.

The details of his military service have been kindly supplied from official quarters as follows :—

Gazetted Lieutenant, Royal Artillery, 12th September 1872, and was posted to the 5th Brigade at St. Thomas's Mount, Madras. Was transferred the same year to the 8th Brigade at Lucknow, which moved that year to Meerut, Punjab, where he remained for three years, until he was posted on 26th January 1877, to No. 1 Mountain Battery, Punjab Frontier Force, at Kohat, North-West Frontier. Took part with this Battery in a punitive expedition against the Jawaki Afridis, penetrating into their territory, and capturing several villages. He had leave on medical certificate for 18 months from 21st December 1877, after which he was posted to the 9th Brigade at Dover.

Student on Advanced Class at Artillery College, 1880–1882.

Instructor in Mathematics, R.M.A., 1882–1888.

Inspector W. Stores, 1888–1891.

Instructor and Professor, Artillery College, 1891–1897, in the subjects of Electricity and Optics.

It was his return to Woolwich in 1882, and his friendship with Sir George Greenhill (then a Professor at the Artillery College, Woolwich), that changed the current of his life. To quote the words of Sir Joseph Larmor in a letter to the *Times* of 1929 December 31 :—

" At that time the Theory of Algebraic Forms was in the full flight of development by the activities of Cayley and Sylvester and Salmon, this being the one great domain in the vast range of modern abstract mathematics whose creation may be claimed to be predominantly British. The young captain threw himself with indomitable zeal and insight into the great problems of this rising edifice of science ; and in a very short time he was to be counted as conspicuous among the leaders, largely by invention of new methods of approach. So complete was his scientific absorption then, and during successive tenures as Instructor and Professor at Woolwich, that one was accustomed to

hear his military friends refer in chaff to him as ' a good soldier spoiled.' Anyhow they were proud of him; and equally proud was the scientific world into which he had so thoroughly forced an entrance. . . . His most remarkable gift was great native insight into the theory of permutations, a sort of glorified chess practice, and the harvest that it could yield in other domains, at first sight unlikely. This mass of work was recognised by the award of one of the Royal Medals by the Royal Society in 1900."

One phrase in this sympathetic appreciation may perhaps be emphasised, viz. that referring to " the harvest that [the theory of permutations] could yield in other domains, at first sight unlikely." MacMahon would have specially welcomed this view of his work: for the ordinary view of pure mathematics as an isolated subject was thoroughly distasteful to him. He had an earnest faith that its relationships to other domains, though they might be obscured for the moment, would ultimately emerge into the clear light of day. He gave eloquent expression to this view in his Presidential Address to Section A at the Glasgow meeting of the British Association in 1901.

" It will be gathered from remarks made above," he said, " that I regard any department of scientific work, which seems to be narrow or isolated, as a proper subject for research. I do not believe in any branch of science, or subject of scientific work, being destitute of connection with other branches. If it appears to be so, it is especially marked out for investigation by the very unity of science. There is no necessarily pathless desert separating different regions. Now a department of pure mathematics which appeared to be somewhat in this forlorn condition a few years ago, was that which included problems of the nature of the magic square of the ancients."

And he proceeds to give a masterly summary of the rescue of this forlorn department. Earlier in the address he had led up to his avowal of faith by giving illustrations from the theory of invariants and the combinatorial analysis " with which I have a more special acquaintance " ; but this is scarcely the place in which to follow him further.

A still earlier part of the same address, however, is worth recalling because of its relationship to our own Society. After some introductory remarks on the history of mathematics in England, he paused a moment to " rescue from an oblivion which seems to threaten it " the history of the Mathematical Society of Spitalfields, founded in 1717 by Joseph Middleton, a writer of mathematical text-books, and absorbed into the Royal Astronomical Society, with its valuable library, in 1845. The number of members was originally limited to " the square of seven," but later it was successively increased to " the square of eight " and " the square of nine." The subscription was sixpence a week, and entrance was gained by the production of a metal ticket which had the proposition of Pythagoras on one side and a sighted quadrant with level on the other. The members dined together twice annually, viz. on the second Friday in January in London to commemorate the birth of Sir Isaac Newton, and on the second Friday in July, somewhere in the country, in commemoration of the birth of the Founder. It was

found necessary to introduce a rule fining members sixpence for letting off fireworks in the place of meeting. Every member was entitled to a pint of beer at the common expense, and further, every five members were entitled to call for a quart for consumption at the meeting. All these details and much more, MacMahon rescued from the Minute Books of the Society, still in our possession, and recounted for the delight of his audience at Glasgow.

Soon after his Presidency of Section A, MacMahon was elected one of the General Secretaries of the British Association (1903–13), remaining in office until just before the Australian visit. On his retirement he was elected one of the three Trustees of the Association, his colleagues being Lord Rayleigh and Sir Arthur Rücker.

Though the amount of MacMahon's published work is considerable, there is but one paper to his name in our *Monthly Notices* (**69**, 126). It is interesting, however, to note that it concerns a possible "determination of the apparent diameter of a fixed star," and attracted comments from Professor Eddington. But it reads now like ancient history!

The seriousness and importance of his researches in pure mathematics are so thoroughly well established that it can cause no misapprehension to remark that a part of them grew out of a pastime, and another part of them suggested reduction to a pastime.

We may first quote, in illustration of the aforesaid importance, the following opening sentence from his paper on "Combinatorial Analysis. The Foundations of a New Theory," in *Phil. Trans. R.S.*, A, **194** (1900):

"In the *Trans. Camb. Phil. Soc.* (vol. xvi., pt. iv., p. 262) I brought forward a new instrument of research in Combinatorial Analysis and applied it to the complete solution of the great problem of the 'Latin Square,' which had proved a stumbling-block to mathematicians since the time of Euler. The method was equally successful in dealing with the general problem of which the Latin Square was but a particular case, and also with many other questions of a similar character."

Perhaps we may quote also the mere title of one of his "Memoirs on the Theory of the Partitions of Numbers" (*Phil. Trans.*, vol. ccix. A, 1909) which runs: "On the Probability that the Successful Candidate at an Election by Ballot may never at any time have Fewer Votes than the One who is Unsuccessful: on a Generalisation of this Question, and on its Connexion with other Questions of Partition, Permutation, and Combination."

It will be seen that these erudite researches had distinct points of contact with practical life, and we may now recall, as stated above, their connection with pastimes. Simon Newcomb was very fond of the card games which go by the name of "Patience," and in playing one of them a question suggested itself which he referred to MacMahon, who had already dealt with a somewhat similar problem in the *Phil. Trans.* for 1893. The answer appears in the *Phil. Trans.* for 1908 (vol. ccvii.) as a learned memoir of seventy pages!

The converse transition, from philosophical thought to pastime, is represented by MacMahon's *New Mathematical Pastimes*, published by the Cambridge Press in 1921. It opens with the remark of Edwards

to Dr. Johnson, "You are a philosopher, Dr. Johnson. I have tried too in my time to be a philosopher, but I don't know how, cheerfulness was always breaking in." And other literary quotations are scattered through the book in the happy manner to which Eddington had introduced us the year before. The argument starts with the game of dominoes, and it is at once suggested that there should be on each domino not two numbers but three: and later, four. The various possible arrangements, with due attention to boundary conditions, are studied, needless to say with skill and beauty. One of the quotations is from Pope's *Essay on Man*:—

> So from the first eternal order ran,
> And creature link'd to creature, man to man . .
> . . . . . .
> The link dissolves, each seeks a fresh embrace,
> Another love succeeds, another race.

MacMahon was very fond of billiards and was a good player, often to be seen playing after lunch at the Athenæum Club, to which he was elected (under Rule II.) in 1903. The present writer once received a surprising compliment, worth recording here because of its sequel. The editor of a journal asked him to review a book on billiards, and it was natural to refer the editor to MacMahon as the right person for the undertaking. But it was bewildering to learn, in response, that the editor's application had been suggested by MacMahon himself; and the next step was clearly to go and seek an explanation. It appeared that, perhaps from diffidence or amiable laziness, he had really made this suggestion of putting the review into much less worthy hands: though he had the friendliness to help with a few important suggestions: and it is one of these which seems worth noting here. The importance of the "half-ball" stroke in making a losing hazard is well known. MacMahon remarked that it also had a distinct value for the winning hazard, though this had not received proper attention. If the eye were trained to recognise the angle at which a half-ball stroke would send the object ball into a pocket, the winning hazard could be made oftener and more easily. Certainly in MacMahon's play this facility could be observed, though whether his principle is accepted widely seems doubtful. Is it permissible to recall another experience of his? He at one time took lessons in billiards from a well-known expert who after a time professed to have conveyed all the regular information available—or nearly all. "There is one more piece of advice I could give you, which would improve your play considerably," he said, "if you care to pay another guinea; for it lies outside the regular lessons." The guinea was paid cheerfully. "Always chalk your cue before you play, and not after."

"On being co-opted by the University of Cambridge to the honorary degree of Doctor of Science in 1904" (to quote again Sir Joseph Larmor), "MacMahon attached himself by invitation to St. John's College, where he had acquired many friends. Some years ago he and his wife withdrew from London to Cambridge" (he had married, in 1907, Grace

Elizabeth, daughter of the late C. R. Howard of 32 Gloucester Place, W.), " and as a member of the Society of St. John's College he became a most welcome and, as we thought, a happy figure in its life, armed with the knowledge that he brought of the external world. He continued the pursuit of mathematics, by public lectures as well as investigation. His absence was keenly felt when about a year ago a breakdown in health compelled him to retire to Bognor ; his memory will be cherished as one of the most gracious accessions of recent times." After a brief illness he died somewhat suddenly at Bognor on Christmas Day last.

He received many honours. He was elected F.R.S. in 1890. In 1894 he was President of the London Mathematical Society which in 1923 conferred upon him the De Morgan Medal. From the Royal Society he received a Royal Medal in 1900, and the Sylvester Medal in 1919; and he was elected Vice-President in 1917. He was an Honorary Member of the Royal Irish Academy and of the Cambridge Philosophical Society. Honorary Degrees were conferred on him by Cambridge, Dublin, Aberdeen, and St. Andrews Universities, and he represented the Royal Society as a Fellow of Winchester College.

H. H. T.

Walter A. Mátos was born in Cuba on 1874 October 31. He was educated at the Philadelphia Central High School, where his love for astronomy was first roused by Professor Monroe B. Snyder, who placed at his disposal the equipment of that institution. Here he acquired an accurate knowledge of the fundamentals of astronomy and gained an insight into its problems.

Later he studied at the Philadelphia Episcopal Divinity School and the University of Pennsylvania. In 1898 he was ordained Deacon, and 1899 appointed Rector of Trinity Protestant Episcopal Church, Swarthmore, a post that he held till his death. He was conspicuously successful as a rector, and his influence with the younger members of his parish was remarkable. His study was a museum and laboratory in which his young friends gathered to learn in the most inspiring fashion the principles of physical science, and to be entertained with curious mechanical and literary puzzles. Here were laid the foundations of more than one scientific career.

He found an outlet for his astronomical activities in the Sproul Observatory of Swarthmore College, and from 1915 onwards acted as a volunteer observer, and took a regular and definite share in the programme of taking photographs with the 24-inch telescope for the determination of stellar parallaxes.

On visitors' nights he was very much in demand, as he possessed the faculty, not only of showing celestial wonders, but also of arousing a real interest in them. He took a prominent part in the activities of the Camden Astronomical Society, now the Rittenhouse Astronomical Society of Philadelphia, and for many years served as secretary and treasurer.

Mátos never married, but lived with his blind mother, to whom he was most touchingly devoted. Some years ago his doctor informed him

that his mother would never be able to come downstairs again, so he promptly installed a lift, and proudly related to his friends the number of times that she had been up and down in the lift.

He was a member of the American Meteorological Society, of the American Astronomical Society, of the Swarthmore College Chapter of Sigma Xi, and of the British Astronomical Association.

He died on 1929 August 9, in the Episcopal Hospital, Philadelphia, after a brief illness.

He was elected a Fellow of the Society on 1919 March 14.

L. J. C.

Willie Venner Merrifield was born in 1859 August at Mary Tavy, near Tavistock, Devonshire. He was educated at a Grammar School in Plymouth, and afterwards went to St. John's College, Cambridge, where he took the Mathematical Tripos. On leaving the university he worked for a time under his father, the late John Merrifield, LL.D., who was also a Fellow of the Society, at the Plymouth Navigation School—an institution which survived as a private school until a few years before the War, when it was taken over by the local education authority. Merrifield was later appointed principal of the Nautical College, Liverpool, where he remained until his retirement in 1924. He married a Miss R. H. Woodrow, of London, and leaves two sons and a daughter. He was naturally chiefly interested in the nautical aspects of astronomy, and in 1916 published a pamphlet on *Tidal Soundings and Diagrams*. In earlier days he assisted his father in the preparation of books on navigation and allied subjects, and apparently helped in re-editing them later. He died on 1929 July 29 at Waterloo, Liverpool, in his seventieth year.

S. Lynn Rhorer was an American amateur astronomer whose life was mainly devoted to the cause of popular astronomical education. He described his part in the progress of astronomy as "bringing the stars to the man in the street," and few who have worked to this end can have had the satisfaction of seeing their labours more strikingly crowned with success. His efforts culminated in 1923, when, after a visit to Miami, Florida, he decided that the tropical skies and the unusual climatic conditions made it an ideal spot for popular education. He thereupon conceived and began to put into operation a plan which seemed fantastic in the extreme. He obtained permission from the authorities to set up a 5-inch Clark reflector in a park in the "downtown" section in the centre of the city, and stood by it ready to satisfy the curiosity of any passer-by who wished to see the spectacle of the skies. With the most interested of his observers he hoped to form an observatory staff, and, by the addition of one telescope per year up to a total of seven, he planned to establish an institution for them to conduct, which would be worthy of the high object he had in view. The project was completely successful. The response to his initial effort was immediate, and the "Southern Cross Observatory" became, exactly as he had anticipated, one of the most effective instruments

in existence for popular instruction in astronomy. The unique setting of the observatory—in a grass-grown plot surrounded by palm trees and far enough from the brilliant lights of lofty buildings to allow good seeing—was no doubt an appreciable factor in the success of the scheme.

The observatory was opened at seven o'clock every evening, and although in theory it was to close at ten, the closing time depended in fact on the enthusiasm of the observers. When interesting objects rose late, continuous observation until sunrise was not unusual. Afternoon sessions for observing the Sun were soon added to the activities, and as the organisation developed, brief illustrated lectures were made part of the daily programme. The illustrations were projected on a screen in the park, and the spectators saw them from seats on the grass or whatever other viewpoints were available. The observatory attained the dignity of a public institution, and it was not unusual to find a queue of spectators for each instrument extending beyond the confines of the park. On one evening 2000 people were recorded as visitors. The expenses for all this work were entirely defrayed by Rhorer personally. How much the success of this unique scheme owed to genuine foresight, and how far it was a triumphant vindication of faith, it is, of course, impossible to say, but the whole undertaking must surely be regarded as one of the most romantic incidents in the modern history of astronomy.

Although popular instruction was his chief interest, Rhorer was also an enthusiastic astronomer himself. He was the first man in his longitude to observe Nova Aquilæ in 1918, and was an active member of the American Association of Variable Star Observers. He was elected a Fellow of the Society on 1926 December 10. One of his outstanding personal characteristics was his extreme modesty. He avoided publicity for himself as completely as possible, forbidding the use of his name by chairman or speaker at any of the lectures—frequently by some of the leading astronomers of America—which were arranged. The largest hall in the city was obtained for the most important of these lectures, and its capacity was often barely sufficient for the accommodation of the audience.

During the season of 1929 ill-health prevented him from attending the observatory in person, although he continued to be its guide and inspiration, and on 1929 April 21 he died at his home in Atlanta. It is pleasing to know that the members of the staff residing in Miami, with a group of visiting members, have determined to carry on the work as a monument to Rhorer, and to extend it if possible. Arrangements are being made to place the institution on a solid foundation and to continue its present open character.

Canon Alfred John Parkman Shepherd, who had been a Fellow of the Society since 1878 April 12—a period of more than fifty years—died on 1929 December 1 after a short illness. He was born at Clifton, Bristol, in 1855, and educated at Queen's College, Oxford, where he took his B.A. degree in 1876 and his M.A. degree in 1880. He was a well-known scholar of the University in his day, and in 1878 he was

ordained deacon, and in the following year priest, at Oxford. From 1877 to 1882 he was a Fellow of his College.

He began his ministry with a brief period as Chaplain of St. Andrew's Railway Church, Lahore, and Chaplain to the Bishop of Lahore. Returning to England in 1879, he became Lecturer and Chaplain of his old College for two years, and during the following five years he was Director of the Church Missionary Children's Home at Highbury. From 1885 to 1887 he held his first rectorship, at Upton Scudamore, Wiltshire, and in the latter year he was appointed Rector of Sulhamstead Abbots with Sulhamstead Bannister, Reading, a position which he held up to the time of his death. He took a prominent part in the work of the diocese and in Church work generally, and in 1929 August he was appointed honorary Canon of the Cathedral of Christ Church, Oxford. In his later years he was keenly interested in the question of Church schools and Church education, and was one of the promoters and members of the Diocesan Educational Council.

Shepherd took much interest in social work, particularly the administration of the Poor Law. Some forty years ago he was elected a member of the Bradfield Board of Guardians and Rural District Council, and he became chairman of that body in 1911. Outside his religious work, this claimed the greatest share of his attention. Although he was greatly interested in astronomy, circumstances prevented him from taking any active part in it, and this was a source of much regret to him.

In 1881 he married Miss Helen Amey Norton, daughter of John Norton, F.R.I.B.A., by whom he had one son and six daughters. Mrs. Shepherd and five daughters survive him.

Christopher Thwaites was born on 1840 December 9 at 74 Holborn Bridge, St. Andrew's, Holborn, in the City of London, and was the eldest son of Sir John Thwaites, Kt., Deputy-Lieutenant for Middlesex and first chairman of the Metropolitan Board of Works.

The first part of his education took place at Uxbridge and Brighton, and subsequently he entered King's College, London, where he studied engineering with distinction and received a prize for the construction of a lathe.

On leaving King's College he went to Ireland and carried out some extensive survey work for the Sligo Railway. In 1865 he received the appointment of Deputy-Engineer to the city of Bombay and later that of Acting City Engineer. During the five years of his residence in India he carried out a large drainage scheme and also a scheme for a new water supply for Bombay.

He came home in 1870 and engaged in practice at Westminster as Consulting Engineer. This he carried on for two years, and then went to Norwich for three years with the appointment of City Engineer. In 1875 he went to Sunderland as Borough Engineer, a post he held until 1879, when a breakdown in health compelled him to relinquish the office. He came to London for a time, then went to live at Beccles, Suffolk, until the year 1893. Then he started a private practice in

Norwich, which he maintained until 1896. Retiring in that year, he removed to Sutton, Surrey, where he lived until his death on 1929 December 4, five days before his eighty-ninth birthday. He was buried in the same vault as his father at Nunhead on his natal day.

Thwaites's first acquaintance with astronomy came while he was at Brighton, the headmaster of his school being astronomically inclined. He developed a love for the science which remained with him throughout his long life, the mechanical side appealing very strongly to his engineering instincts.

His first instrument was a $2\frac{3}{4}$-inch refractor, and later he became possessed of a 6-inch. He made many observations of the nebula in Orion with a view to seeing if there was any change in the light from the nebula, but he did not publish his results, although he affirmed his belief that there was no variability.

His most important work seems to have been in connection with total eclipses of the sun, and in 1898 he went to India, taking with him a $4\frac{1}{4}$-inch Cooke photo-visual refractor lent him by G. J. Newbegin. He collaborated with E. W. Maunder and others in organising the B.A.A. Expedition to Talni, Berar, and his previous knowledge of the country marked him out as the proper person to undertake the arrangements. He proceeded to Talni in advance of the main party and selected the site for the observations, and in this he was ably seconded by D. O. Morris. The results of this expedition were some beautiful photographs of the corona.

In 1905 he led the B.A.A. Expedition to Burgos, Spain, taking with him the same instrument, but the results on this occasion were disappointing by reason of some mechanical defect in the driving of the telescope during the exposure of the plate. During the rehearsals for this eclipse King Alphonso XIII. of Spain drove up to the camp and inspected the instruments, and Thwaites had the honour of conducting His Majesty round and explaining the different purposes to which they would be put.

On his return from Spain he purchased the $4\frac{1}{4}$-inch telescope from G. J. Newbegin and for some years carried on observations of sunspots, both visual and photographic.

He was an enthusiastic photographer, his experience beginning with the wet collodion process, and he was conversant with all branches of the art. For some time he was President of the Sutton Photographic Society.

Of the personal side of the man it is not easy to write, for his modesty was innate, but he had an extremely attractive personality and a charm of manner which endeared him to all who counted themselves his friends. He was widely read, and his knowledge of things in general was always at the disposal of those who sought his advice.

He was very fond of music and played the violin : he also possessed a pleasing tenor voice, and while living at Beccles he sang in the choir of the parish church.

He was a keen sportsman with the gun and rod, and in his younger days was a very good swimmer.

He was gifted with a keen sense of humour, and although he liked to play an innocent joke upon anyone whom he knew well, it was always so neatly done that no offence was ever caused.

About 1875 Thwaites married Miss Emma Grove, by whom he had two sons and a daughter.

He was elected a Fellow of the Society on 1886 February 12.

A. M. N.

Worcester Reed Warner was one of the founders of the well-known firm of engineers, the Warner & Swasey Company, which is responsible for the mounting of some of the largest telescopes in the world. He was born on 1846 May 16 on a New England farm near Cummington, Massachusetts, and educated in the rural district school. Agricultural pursuits occupied his boyhood and early manhood, but he acquired also a fondness for astronomy, and, with the encouragement of his mother, devoted his spare time to constructing telescopic models with such means as were available. His growing taste for this type of work led to a determination to leave the farm for industry, and at the age of 19 he entered the Boston drafting-room of a machine works, from which he was soon transferred to the company's shops in Exeter, New Hampshire. Unknown to him, another lad, Ambrose Swasey by name, had had a closely similar career. Born in the same year as Warner on another New England farm, he had found the details of the machinery used in farm work more to his taste than the work itself, and he likewise had decided, at the same age of 19, to give his whole time to mechanics. By a remarkable coincidence he joined the same shop as Warner at about the same time, and the friendship which then began remained unbroken to the end, with results which everyone knows.

Those results, however, were not achieved without difficulty. "The apprentice in those days," we are told, "was viewed more as a convenient drudge than as an asset to be made into a valuable entity, and the two farmer boys had the same ample lack of opportunities as their comrades." At the completion of their apprenticeship in 1870 they entered the employ of Messrs. Pratt & Whitney in Hartford, Connecticut, where, after a short time, Warner was placed in charge of one of the firm's largest departments and was entrusted with the management of the company's exhibit at the Centennial Exhibition in Philadelphia. After working for a time as foreman he undertook, according to the custom in those days, to build machines under contract, and attracted attention by, among other things, greatly reducing the time of production.

The idea that the two friends should set up in business for themselves came to fruition on 1880 May 5, when the firm of Warner & Swasey was established on the strength of the combined savings of the partners up to that time. Four young men from Connecticut formed with them the nucleus of the new organisation. The headquarters of the firm were originally in Chicago, but owing to the difficulty of getting skilled mechanics so far from the industrial centres of New England, a transfer to Cleveland was arranged after about a year's working. In the early activities of the firm astronomy was not conspicuous, hand lathes and

sewing machines being among the principal objects dealt with. Nevertheless a 9½-inch equatorial was designed and constructed in 1881, which showed marked improvements on previous instruments of this type, and the contracts which came in for telescopic work slowly but steadily increased. The initiative for this work came from Warner, whose early interest in astronomy had not waned during the years of engineering progress, and he succeeded in inspiring his partner with something of his own enthusiasm. The first of the great telescopes with which the firm is particularly associated was the 36-inch refractor of Lick Observatory, which was erected during the winter of 1886–87. Warner & Swasey were responsible for the design and construction of the framework and the mounting of the telescope ; they had no concern with the optical parts of this or any other instrument. The success of their efforts led to a commission from the Government to construct a similar mounting for the 26-inch objective of the United States Naval Observatory, Washington, and shortly afterwards the design and construction of the 40-inch Yerkes refractor as well as the 90-foot dome and 75-foot elevating floor, were entrusted to them. This is no place to record the many important astronomical instruments which the firm has to its credit, but we can hardly omit to add the 72-inch reflector at the Dominion Observatory, Victoria, B.C.

In 1900 the business was incorporated under the name of the "Warner & Swasey Company "—a change thought desirable in order to provide for a larger organisation and further expansion in facilities. Both partners, happily, were able to continue in active co-operation, and in 1920, on the occasion of the 20th anniversary of the company and the 40th of the partnership, a memorial volume was published containing particulars of the firm's activities and personal notes relating to the founders and prominent workers. Warner died on 1929 June 25 at Eisenach, Germany, at the ripe age of 83. He had been a Fellow of the Society since 1899 January 13.

Marie Henri Andoyer, who died on June 12, was one of the most distinguished of French scientists. His work extended through all branches of mathematical astronomy, he constructed extensive tables of mathematical functions, and in his earlier years he was active as an observer at Toulouse Observatory. By steady and unremitting labour for the last forty-five years he accomplished much enduring work. Throughout most of this time he was a teacher who loved teaching, and his contributions to astronomy have been enhanced by several excellent textbooks. For twenty years he was a member of the Bureau des Longitudes and in 1911 he succeeded Radau as editor of the *Connaissance des Temps*, in which he played an important part in the development of astronomical ephemerides. It appeared that his work might be finally crowned by the directorship of the Paris Observatory, but this distinction he refused.

Andoyer was born at Paris on 1862 October 1. His early education was at the Lycée St. Louis, and from this school he went at the age of nineteen to the École Normale Supérieure. Here he specialised in pure mathematics, turning later towards celestial mechanics, in which subject

he took his doctor's degree. For eight years from 1884 he was engaged at Toulouse filling the double rôle of teacher at the Faculty of Sciences and assistant at the observatory. During this period he displayed in a marked degree the manifold activities which characterised his whole life. His theoretical researches at this time concerned the general equations of celestial mechanics, the constancy of the semi-major axes of the planetary orbits, and the inequalities in the motion of the moon. Up to the time of his marriage he lived in a room allotted to him at the observatory. He was in charge of the astrographic work, prepared the list of reference stars, and took the first plates. He also made observations of the eclipses of the satellites of Jupiter and Saturn, and made various other miscellaneous observations.

In 1892 he was recalled to Paris to assist at the Sorbonne in the mathematical department, and to give courses of lectures on celestial mechanics and practical astronomy. In 1903 he was elected professor and, as already stated, he became director of the *Connaissance des Temps* in 1911.

As is well known, the most exhaustive attempt to give a completely general algebraical theory of the motion of the moon was made by Delaunay. For practical purposes it is known that a greater degree of numerical accuracy with less labour can be obtained by starting with a numerical value of the mean motion, such as had been done by Hansen, and has since been done by Brown. Much of Andoyer's labours were concerned with verifying Delaunay's expressions. When at Toulouse he had found some errors in Delaunay's work involving terms of the eighth and higher orders (*e.g.* $m^6e^2 \sin 2D$). In his *Recherches supplémentaires de Delaunay* he stated that beyond the seventh order all the terms are inexact, although the initial terms are correct. By the use of two methods which give results in agreement with each other and with Brown's theory, he was able to find many errors in Delaunay. This work he carried on up till the end of his life, the last paper on the subject being published in 1928.

Another branch of celestial mechanics treated by Andoyer was the theory of intermediary orbits, following the lines of Gyldén. In this problem he dealt with cases of near commensurability, especially with reference to planets of the Hecuba type. In 1906 he wrote on the relative equilibrium of n bodies and on periodic orbits near the positions of relative equilibrium.

Andoyer was an excellent teacher who took great pains over his lectures, many of which he published for the use of students in general. His purely mathematical books include, besides numerous smaller works, *Leçons sur la théorie des formes et la géométrie analytique supérieure*. This book indicates his great skill in handling problems in analytical geometry—a subject on which he wrote a number of original papers. His *Cours d'Astronomie*, including volumes on theoretical and practical astronomy, has gone to several editions. A little book, *Théorie de la Lune*, giving all the inequalities in the three co-ordinates to the fourth order of small quantities, may be recommended to anyone wishing to read an introduction to the complexities of the moon's motion. His

more recent work, *Cours de mécanique céleste*, in two volumes, may be described as intermediary between the works of Tisserand and Poincaré. The aim is to give simply, yet completely, the practical solution to the real problems of celestial dynamics. After dealing with the general problem of elliptic motion and its perturbations he considered the special cases of the major planets, the moon, and the great satellites of Jupiter.

One would have thought that Andoyer would have found his time fully occupied by teaching, writing, direction of the *Connaissance des Temps* and original researches, but his unwearied spirit drove him to the apparently mechanical labour of computing tables of mathematical functions. Between 1911 and 1918 he published four large folio volumes: (1) Tables of Logarithms of Trigonometric Functions to 14 Decimals (1911); (2) Tables of the Natural Trigonometric Functions to 15 Decimals, three volumes (1915, 1916, 1918). He also made computations for tables of addition and subtraction logarithms, and for tables of logarithms of numbers to a large number of decimals. For several years he regularly devoted three hours daily to this work.

Enough has been said to show that he was a man of boundless energy. Many British astronomers will have pleasant remembrances of his wholehearted enthusiasm at the various meetings of the International Astronomical Union, of which he was a vice-president at the time of his death, having acted as president of the Commissions on Celestial Mechanics and Ephemerides. In the words of the president of the Academy of Sciences, of which he became a member in 1919: "D'une rare modestie, Andoyer masquait sous une bonhomie un peu brusque un cœur excellent, il sera vivement regretté parmi nous." We may add that his death will be deeply regretted in other countries besides his own.

He married when at Toulouse and had two sons and a daughter. The death of the elder son, killed early in the war, was a heavy blow.

He was an Officer of the Legion of Honour.

He was elected an Associate of the Society on 1914 November 13.

J. J.

Georges Lecointe, Honorary Director of the Royal Observatory of Belgium, an Associate of the Society, and Correspondant of the French Academy of Sciences, was born at Antwerp on 1869 April 29. After a preliminary education he joined the Military School at that city in 1886, and began his career in the service of the Belgian Government. From 1894 to 1897 his services were transferred to the French Government and he joined the Mediterranean Squadron with the rank of "Lieutenant de Vaisseau," taking up his residence in the Observatory of the Bureau des Longitudes, of which he became Correspondant in 1914. From 1897 to 1899 he took part, as second in command, in the *Belgica* Antarctic Expedition, commanded by M. de Gerlache. His valuable work in connection with this undertaking attracted the attention of the Belgian Government, and he was assigned the direction of the astronomical, geophysical, and meteorological services at the Royal Observatory of

Belgium at Uccle. On taking over this work he had considerable arrears to make up, but he proved more than equal to the task and filled the office with great distinction. He published a series of volumes of the first importance on a variety of subjects, including the planets Venus, Mars, and Jupiter, the distribution of the stars in relation to the Milky Way, observations of the transit of Mercury, and meridian work, and, in addition, he took a prominent part in the preparation of the Astrographic Catalogue for the Paris zone. He devoted much attention, also, to the preparation of the Carte du Ciel. Among his contributions to geophysics may be specially mentioned his magnetic and seismological observations and his researches on the temperature of the soil. Lecointe participated in the conferences at Paris on the Distribution of Time by Wireless in 1913 and 1922, and here his knowledge of other international societies made his advice of great value in drawing up the Statutes of the Association. He served in the War and was driven into Holland and interned there. Near the end of the War, however, he was allowed on parole to make a short visit to England for astronomical purposes. In 1918–19 he played an important part in the creation of the International Research Council and the various international scientific unions associated therewith. His services to astronomy were recognised by the Society by his election, on 1921 June 10, as an Associate. He died on 1929 May 27 at the age of 60 years.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.
(*Director, Sir Frank Dyson, K.B.E., F.R.S., Astronomer Royal.*)

Transit-Circle.—The number of transits observed during the year 1929 was 9288, including 157 of the Sun and 109 of the Moon. The observations are reduced to 1925·0 as far as 1929 June. The ledgers of the clock and azimuth stars are complete to the end of 1928 and those of zone stars to 1927 August. The observing programme comprises all stars down to magnitude 8·0 and between declinations + 32° and + 64°. This programme was commenced in 1922 and will be completed in the present year. In addition, observations have been carried out on a selected list of stars, north of declination − 15°, which will be used as reference stars for the observation of Eros in the opposition of 1930–31. These observations were commenced in 1925 and have now been concluded. In all 2105 observations of 471 stars have been obtained. The results have been communicated to Professor Kopff.

An ephemeris of Vesta, based on Leveau's tables, has been computed for the year 1916 for a comparison with the observations, as no published ephemeris was available.

Altazimuth.—The instrument has only been in use for a short time during the year to supplement the observations of the Eros comparison stars made with the transit-circle. During the year 446 transits and 422 zenith distances were observed. Including those previously obtained, observations have been made of 434 stars.

Cookson Floating Zenith Telescope.—During the year 275 plates for the variation of latitude were obtained. This number is a record, but there was a deficiency of plates in April (13 plates), October (11 plates), and November (11 plates) owing to bad weather. The measurement and reduction are in hand.

On October 31, the object-glass was removed and the three lenses cleaned. After their replacement, the instrument was refocussed and a fresh scale determination made.

28-*inch Refractor.*—During the year 594 observations of 357 double stars were secured. Arranged according to separation they are :—

Under 0″·5	107	observations.
0″·5–1″·0	178	,,
1″·0–2″·0	197	,,
Over 2″·0	112	,,

On Sunday nights and on other nights in which the instrument has not been used for double-star observations it has been employed by Dr. Steavenson for the observation of faint variable stars.

As the result of a suggestion for which the Observatory is indebted to Mr. F. J. Hargreaves, the water-drive of the telescope has been replaced by an electric drive of the Gerrish type. It consists of a direct drive from an electric motor, the power supply being controlled by a pendulum. The construction was carried out in the workshop. The drive has now been in operation for six months. It has given complete satisfaction and incidentally has demonstrated the fine workmanship of the driving circle.

Thompson Equatorial.—During the year 1464 plates suitable for the measurement of stellar parallax have been taken and 632 have been measured.

As mentioned in the last report, the breech end has been modified to facilitate the work at the telescope. Six aluminium plate-holders have been provided which permit of easy reversal in the breech end. The practice now is to obtain two exposures on each star and to reverse the plate through 180° between them. This practice was commenced first for the elimination of film distortion on plates which had been desensitised with copper sulphate, and has now been extended to all plates.

As was expected, the output has been increased, but as it has been found undesirable to commence measurement until a parallax series is completed, a corresponding increase in the rate of measurement has not yet taken place.

The parallaxes of 26 stars were published in the *Monthly Notices* for 1929 November.

With the 30-inch reflector the work on colour temperatures of stars has been continued. The work on the selected standards, mentioned in last year's report, has been completed, and the results published in the *Monthly Notices* for November. Results for 19 other stars which had been compared with the standards were also published. During the year 179 observations of pairs of standards were obtained and 98 observations of other stars.

In order to economise time at the telescope, the use of the coarse grating as a means of securing a photometric scale on each plate has been discontinued. A small slit spectrograph similar in dispersion to the stellar spectrograph has been constructed. With this spectrograph the scale is printed on each plate by means of slits of determined widths.

Astrographic Equatorial.—During the year 21 fields were photographed through the glass for the determination of proper motions of stars in the Greenwich Astrographic Zone. 60 plates were measured. The telescope was remounted at Greenwich on 1929 July 15–20 on its return from the Eclipse Expedition to Siam.

The measurement and reduction of plates in Zone + 73° has been completed. Zone + 75° has been rephotographed and the plates measured and reduced from R.A. $5^h\ 15^m$ to $20^h\ 45^m$.

During the year vol. v., Astrographic Catalogue, has been published. It contains Proper Motions for 14,528 Stars in Zones +64° to + 71°

(inclusive). It also includes a catalogue of all double stars of less than 30″ separation, compiled by Dr. Groot, and a list of measures, made on the photographs, of all pairs with less than 10″ separation.

Photoheliograph.—Photographs of the Sun were obtained on 267 days at Greenwich and on 337 days at the Cape. On five days, photographs were not taken at either Observatory, but in each case plates from Kodaikanal were available. On November 1, eight photographs were secured with the Thompson photoheliograph of the partial eclipse of the Sun for the purpose of timing the first and last contacts.

For 1929 the mean daily spotted area, corrected for foreshortening, was approximately 1250 millionths of the Sun's hemisphere. The published values for the preceding five years 1924–1928 are 276, 830, 1262, 1058, and 1390 respectively.

A discussion of the recurrence of magnetic storms, from Greenwich data 1874 1927, has been made and the results published in *Monthly Notices*, **89**, 641. The Photoheliographic Results for 1927 were published during the year. This volume includes catalogues of magnetic storms covering the period 1874 to 1927.

A Spectrohelioscope has been presented to the Observatory by Dr. Hale. It was received on October 2 and set up in the South Attic of the New Building. Observations with it were commenced on November 21.

Clock and Time Service.—The free-pendulum clock Shortt No. 11 was substituted for Shortt No. 3 as standard sidereal clock on August 1. Clock No. 3 was overhauled, a few minor alterations being made to the movement, and an invar bob was fitted to the pendulum during the autumn. Since November 22 the clock has been kept running as reserve standard, regular comparisons being made with No. 11. A discussion of the performance of the two clocks during the year is given in *Monthly Notices*, **90**, No. 3.

The Mean Time Free-Pendulum clock Shortt No. 16 has controlled all mean time clocks used for time-signal distribution throughout the year. The transmission of wireless time-signals through Rugby and the B.B.C. stations, in addition to the service of hourly telegraph signals, has been maintained regularly.

The reception of wireless time-signals from Rugby, Nauen, Annapolis, and Bordeaux stations has been maintained, and the results of the comparisons circulated in *Notices to Mariners*.

Observations with Transit B.—Observations for clock correction were made on 72 nights.

Eclipse of the Sun.—The weather conditions for the eclipse of the Sun on May 9 were bad at both observing stations, so that the observations to determine the gravitational deflection of light by the Sun failed. At Alor Star, however, Dr. Jackson secured five large-scale photographs of the prominences and the inner corona. The definition was very good. Several photographs were also taken with short-focus lenses through red filters. A report of the expeditions is given in *Monthly Notices*, **90**, 121. All the instruments were returned safely to the Observatory in June and July.

Printing.—The volume of Greenwich Observations for 1927 and its

separate parts have been distributed. Vol. v. of the Astrographic Catalogue (Proper Motions of Stars, declinations + 64° to + 72°) has also been distributed.

The printing of the Greenwich Observations for the year 1928 is nearing completion.

Miscellaneous.—Dr. Carl Schalén of Upsala, Mr. Kasz of Manchester University, and Mr. C. H. Smiley of Berkeley, California, each visited the Observatory for a part of the year.

Royal Observatory, Edinburgh.

(*Director, Prof. R. A. Sampson, F.R.S., Astronomer Royal for Scotland.*)

Throughout the year the preparation of the new equipment has been the chief pre-occupation. The floor and pillar of the West Dome have been altered to fit them for the 15-inch refractor, which is under complete overhaul and remodelling with Messrs. Grubb, Parsons & Co. The 36-inch is now approaching completion. The mechanical portion was exhibited during the summer in the North-East Coast Industrial Exhibition; since its return to the makers a lattice tube has been constructed, to replace the closed tube originally planned, and some other improvements have been made. A great deal of time and care has been spent upon measuring a succession of Hartmann plates, to test the progress of the great mirror to a perfect figure. The theoretical diameter of a star at the principal focus was reduced to 0″·3 or 0″·4, after which it was decided to discontinue further work upon it. The spectrograph by Messrs. Adam Hilger, Ltd., is also in the final stages of construction.

All the regular routine has been continued on the same lines as heretofore. Time has been determined on every occasion possible with the transit-circle; daily comparison by the microchronograph of the four clocks, Riefler No. 258, Leroy No. 1230, Shortt No. 0, and Shortt No. 4, has been made. A new chronograph by H. Wetzer has been brought into use, to replace the Fuess chronograph for general purposes, and has proved very satisfactory. A connection has been made between this chronograph, the siphon chronograph of the Wireless Room, and the microchronograph to permit a determination of relative lag at any time. The clock Leroy was converted from sidereal to mean time in February, and was put in control of the distribution of time to the town circuit in that month. A new form of relay to control the temperature in its cell has been under trial. The clock Riefler was cleaned, and since has given occasional trouble in tripping seconds. It was opened and examined, but no fault could be found. Prolonged difficulty in a leak in the case of clock Shortt No. 0 was finally solved by the construction of a new form of tap. The case of Shortt No. 4 is at present failing to hold its vacuum, but the fault has not been located.

The reception and recording of wireless time-signals from Bordeaux, Rugby, Nauen, and Annapolis daily has been very satisfactory throughout the year.

The solar spectrograph has continued in use to obtain plates for the determination of the equatorial value of the solar rotation. The measurement of the plates obtained is in an advanced state. A new micrometer obtained from Adam Hilger, Ltd., of their type L18, has proved very satisfactory.

The programme of observation of the spectra of stars down to the third magnitude with the photo-visual telescope and objective prism was brought to a conclusion in April, with an average of about seven new observations of each star. The telescope was then dismounted from the West Dome and re-erected in the Garden Dome; it has been furnished with a new control clock (constructed by James Ritchie & Son) upon Steuart's pattern; in this clock, the performance of which is still under trial, the telescope is driven with the minimum of gearing by a motor, the rate of which is controlled by a seconds pendulum, securing average synchrony.

The spectra obtained have been converted into photograms by the Koch-pattern photometer. The records have been measured completely and reduced, and their discussion is in an advanced state.

The photometer has been overhauled and partly reconstructed, with some minor but convenient improvements. The photo-electric cells, originally fitted and made in the observatory, had shown some loss in sensitivity. After considerable trouble a satisfactory pair to replace them was furnished by the laboratory of the General Electric Co., Ltd.

Discussions are proceeding with the object of securing the printing of the astrographic measures of the Perth (W.A.) Zones, but no decision has yet been made. A large mass of the work is ready for the printer, and the remainder could be produced to date as required.

The routine of seismological and meteorological observation has continued as heretofore.

Royal Observatory, Cape of Good Hope.
(*Director, Dr. H. Spencer Jones, H.M. Astronomer.*)

Reversible Transit-Circle.—The number of meridian transits observed during the year was 11,873. The Sun was observed on 207 days, Venus on 153 days, and Mercury on 89 days. In addition to the programme of observations, commenced in 1925, of zodiacal stars and of stars brighter than $7^{m}\cdot5$ south of -30° Dec., observations were continued of the second list of reference stars for the opposition of Eros, 1930–31. 354 stars in this list have been observed four or more times, 41 stars have received from one to three observations, and 7 stars (all north of the equator) have not been observed. Of the stars in the list south of the equator only 3 have not received at least four observations. The results of these observations, in the form of mean places for 1930·0, have been forwarded to Professor Kopff for incorporation in the General Catalogue of Eros reference stars which he is preparing.

Current reductions are well advanced and the results to 1928 June 6 have been entered in the ledgers.

Zone Observations.—The wide-angle triplet lens of 6 inches aperture, covering a field of 25 square degrees, made by Messrs. Taylor, Taylor & Hobson, has been received. This lens will be used for a programme of photographic zone observations according to methods developed by Professor Schlesinger. The zone − 30° to − 35° Dec. will be observed first, and thereafter successive zones of 5° width, southwards to the pole. The comparison stars for the first zone have been selected. It is proposed to observe these by differential methods with the 8-inch (non-reversible) transit-circle. Before these observations could be undertaken, reconstruction of the eye-end of the instrument was necessary; for this purpose a new micrometer screw was ordered from England. The long delay in supplying this screw has considerably retarded the inauguration of the programme.

The camera for the wide-angle lens has been constructed in the Observatory workshop and mounted on the astrographic telescope. Preliminary adjustments and tests have been commenced.

The long screw measuring machine for the measurement of the plates has been received from Messrs. Adam Hilger, Ltd. The investigation of the periodic and progressive errors of the screw has not yet been undertaken, owing to the microscope supplied with the machine not having been in accordance with requirements. A new and satisfactory microscope has recently been received.

Heliometer.—Observations of the major planets near opposition have been continued, and the following observations secured :—

Opposition of	Neptune	.	72	obs.	in	distance	on 6	nights.
,, ,,	Saturn	.	60	,,	,,	,,	,, 6	,,
,, ,,	,,	.	24	,,	,,	position angle	,, 3	,,
,, ,,	Uranus	.	44	,,	,,	distance	,, 7	,,
,, ,,	,,	.	24	,,	,,	position angle	,, 4	,,
,, ,,	Jupiter	.	60	,,	,,	distance	,, 9	,,
,, ,,	,,	.	8	,,	,,	position angle	,, 1	,,

Victoria Telescope.—The telescope was in use on 250 nights during the year for stellar parallax determinations. 1847 plates were secured. 1685 plates were measured. The parallaxes of 213 stars have been determined and the results communicated, in two lists, to the Society.

One out-of-focus plate of the globular cluster 47 Toucanæ was secured at the request of Professor Schlesinger in connection with the investigations by Dr. Schilt on the distribution of light in globular clusters.

Astrographic Telescope.—The rephotographing of the Cape Astrographic Zones having been completed, the instrument has been out of use during the year. The photoheliograph has been dismounted and the wide-angle lens camera mounted in its place. The whole instrument has been thoroughly overhauled.

During the year, 679 plates of the Cape Astrographic Zones were measured, either direct or reverse against the plates of the earlier series, for the determination of proper motions. The present position of this

programme is that the measurement in both positions of the plates in zones − 41°, − 42°, − 43°, − 46°, and − 47° has been completed; the measurement of zones − 44°, − 45°, and − 48° is well advanced.

Photoheliograph.—The instrument was dismounted on June 6 and re-erected on the mounting of the 7-inch telescope. The change was accomplished without losing any photographs of the Sun. 698 photographs were secured on 337 days to supplement the Greenwich series. Visual observations for zero were made weekly. Original negatives to November 28 and duplicate negatives to December 13 have been sent to Greenwich.

Occultations.—9 observations of disappearance at the dark limb, 3 of disappearance at the bright limb, and 4 of reappearance at the dark limb were observed.

The rediscussion of the material contained in Newcomb's Occultation Memoir, which has been in hand for some time, has been completed. A summary of the results has been communicated to the Society recently. The derived values of the Moon's elements are generally in close agreement with Brown's adopted values. From the parallactic inequality, the value 8″·796 ± 0″·004 for the solar parallax was derived.

Night-Sky Observations.—Observations of the brightness of the night-sky were secured on 153 nights, in continuance of the co-operative scheme arranged by Lord Rayleigh. Discussion of the observations secured at the Cape shows the existence of small but well-marked variations with 12-monthly and 6-monthly periods. The observations at Canberra and in England are found to show similar periodicities but with larger amplitudes. The full discussion of the results has been communicated to the Royal Society.

Time-Service and Wireless Time-Signals.—The emission of the international (Onogo) type of time-signal at 23^h S.A.S.T. from the Slangkop wireless station has been regularly continued. The Shortt-Synchronome free-pendulum mean time clock, with magnetic correctors, for the control and synchronisation of the emitting apparatus, was received towards the end of the year and is being installed.

Time-signals were sent out daily at 5^h and 8^h p.m. by the African Broadcasting Association.

The following observations of the scientific rhythmic signals sent out from Bordeaux and Rugby were obtained during the year :—

		No. of Days.
Bordeaux	8^h	273
,,	20^h	83
Rugby	10^h	299
,,	18^h	72

The signals are observed aurally, using an 8-valve Marconi receiver, with directional aerial. A Marconi recorder and local oscillation generator have been purchased; it is hoped that these will enable the small personal systematic errors, to which the present methods of reception are liable, to be eliminated.

Miscellaneous.—The vacancy in the rank of Junior Assistant, referred to in last year's report, has not yet been filled.

During the visit of the British Association to Cape Town, many of the members availed themselves of the opportunity of visiting the Observatory and inspecting its equipment and work.

Armagh Observatory.
(*Director, Rev. Wm. F. A. Ellison.*)

The illness of the Director during the winter and early spring interfered considerably with work. Most of that done was of a routine nature. An occultation of Jupiter on April 11 was observed under rather unusual conditions. Not mentioned by the *Nautical Almanac* except as a near approach, being less than 48 hours from New Moon, it was yet observed with ease. It occurred in daylight at Armagh, between 4 and 5 p.m. Jupiter was quite easily visible, both in the 10-inch and 6-inch equatorials. The Director was an invalid and absent from home at the time, but the observations were made by his son, Mr. M. A. Ellison, F.R.A.S., and a pupil, Mr. John Sheringham. The ease with which the observation was made suggests that the *N.A.* might modify its rule to the extent of recognising occultations of Jupiter and Venus occurring within less than 48 hours of New Moon. Venus could certainly be seen in the telescope when quite close to the Sun's place, and an occultation of this planet at or near New Moon would have a quite exceptional interest. Such an occultation will take place on March 31 next at 8 a.m., and ought to be looked for by observers.

The occultation of Gamma Virginis on April 21 was well seen by the same two observers, the Director being still away. The occultation of Venus, near noon on June 4, was observed by the Director and Mr. Sheringham under difficulties from passing clouds. Venus was clearly visible to the naked eye in the intervals between clouds. To the Director, at the 10-inch equatorial, both disappearance and reappearance were hidden by clouds; but Mr. Sheringham, at the 6-inch telescope, in the East Tower, 100 yards to the N.N.E., saw the disappearance well. The clouds were cumuli with sharp edges, and the parallax of the cloud for 100 yards' ground distance was sufficient to render the disappearance visible at the one instrument while hidden from the other.

The small grant now made annually by the Ulster Government in aid of the funds of the Observatory has enabled the Governors to undertake some urgently needed repairs to the buildings, especially the east wing, containing the Transit Room, Circle Room, and the East Tower—the latter containing the 6-inch equatorial. Decayed woodwork is being replaced, leaks in roofs, etc., stopped, and the doors, windows, and eave gutters painted.

Cambridge Observatory.
(Director, Professor A. S. Eddington, F.R.S.)

The Sheepshanks telescope has been used for experimental work with the photo-electric cell, and no proper motion photographs have been taken. Apparatus is now being constructed in order to try a new plan of measuring the current from the cell, devised by Mr. Moss of the Cambridge Scientific Instrument Company. Results of a short early series of photo-electric observations of B-type stars have been published in the *Monthly Notices* for March.

Eight proper motion fields have been measured and reduced. Dr. Knox-Shaw has kindly had photographs taken of four of the regions of the earlier series of Cambridge proper motions with exposures through blue and yellow filters for the determination of colour index. The regions are in a part of the sky where the star-streams are well separated, and the results should throw light on the connection between spectral type and star-streaming. Two of the regions have now been measured by Mr. H. E. Green and Mrs. Green.

Reference was made last year to the loan by the Society of the Thorrowgood 8-inch telescope. This was erected early in the year, and has proved a valuable addition to the equipment.

Dr. Otto Struve spent the academic year 1928–9 at the Observatory working up and discussing his observational material relating to stationary calcium and sodium lines. He has published many results of great interest, including especially the use of the intensity of these lines as a criterion of stellar distance (*M.N.*, April 1929). Mr. S. Plakidis of the Athens Observatory has investigated (jointly with Professor Eddington) the irregularities of period of long-period variable stars. Investigations by Mr. J. C. P. Miller on the pulsatory theory of Cepheid variables, and by Mr. R. v. d. R. Woolley on the contours of absorption lines, have also reached the stage of publication. A paper by Dr. Smart on the moving foreground of the Large Magellanic Cloud was communicated to the Society in November. During the current academical year Dr. F. S. Hogg of Harvard and Professor W. E. Anderson of Miami University, Ohio, have been working in Cambridge.

Solar Physics Observatory, Cambridge University.
(Director, Professor F. J. M. Stratton, M.A.)

Staff.—Professor H. F. Newall, the former Director, retired in December 1928 after nearly forty years' devoted services to the science of astrophysics, first as Newall Observer and later as Professor of Astrophysics and as Director of the Observatory. He continues happily to co-operate in the work of the Observatory, and in particular he has designed plans for the remodelling of the spectroheliograph for work in Hα as well as in K light, and for use with an interferometer. Fresh optical parts are on order, and it is hoped to have the remodelled instrument available for work by the summer.

A sad loss was suffered by the Observatory in the death of Mr. F. E. Baxandall, who died on 1929 October 31, aged sixty-one. First at South Kensington and later at Cambridge, he unselfishly served his science for many years, gaining a special position among the astronomers of the world from his close detailed knowledge of stellar and laboratory spectra.

Professor C. T. R. Wilson and Mr. P. I. Dee, Stokes Student of Pembroke College, have continued their investigations by the expansion chamber and the cloud-track method at the Observatory.

Mr. E. G. Williams, Trinity College, Isaac Newton Student, has been carrying through some preliminary work with the Huggins 15-inch refractor on stellar spectrophotometry, paying special attention to the standardising of stellar spectrograms for photometric work with comparison spectra obtained through a calibrated wedge simultaneously with the stellar exposure.

Instruments.—Preparations are well forward for bringing the 3-foot Common reflector on loan from the Science Museum into active work. The observing platform and stage have been completed, a Gerrish electric clock-drive is being installed with the assistance of Mr. Hargreaves, and an adjustable gantry has been mounted for the removal of the mirror and cell for silvering.

The programme of spectrophotometric work in view has involved the careful testing of available lenses and prisms, a greater degree of precision in the optical train being necessary for investigations of line contours than for measurements of wave-lengths. It has been found that some of the prisms and lenses in use have become defective, and that certain replacements and readjustments will be necessary in order that the best results may be obtained.

A final design, based on an experimental model, was reached in conjunction with the Cambridge Scientific Instrument Company for a recording microphotometer. The instrument is now nearly ready for delivery, and promises to fulfil expectations. Its purchase was made possible by an offer of generous assistance from Mr. J. H. Reynolds.

Other instrumental preparations include the design and erection of a reflecting stigmatic mounting for a concave grating and a study of its instrumental errors and defects, also the design of a new type of double slit for convenience in stellar spectrophotometry.

Spectroheliograph.—Photographs of the Sun's disc in $K_{2.3.2}$ light were obtained on 125 days (previous year, 112), and photographs of the prominences at the Sun's limb on 109 days (previous year, 101).

Although the rapid decline in solar latitude of the spots observed during the year indicates that the maximum epoch was passed about a year ago, there was a notable secondary increase of activity during the latter part of the year, with many individual groups of considerable magnitude.

In view of possible differences during successive cycles the work on motions of calcium flocculi is being extended to cover two solar cycles.

For the year 1928 October 1 to 1929 September 30, the Director of

the Kodaikánal Observatory has sent 332 spectroheliograms showing the Sun's disc in $K_{2.3.2.}$ light.

Bromide prints of 182 photoheliograms from negatives taken at Greenwich, the Cape, and Kodaikánal Observatories have been received from the Astronomer Royal for the period 1928 January–June.

Study of Prominences.—The records of prominences obtained at Kodaikánal Observatory during the period 1928 January–September have been received through the kindness of Dr. Royds. They have been plotted in continuation of previous work. Two complete cycles are now available for study, and a paper by Mr. Moss dealing with the movements and rotation periods of the prominences is now in the press as a forthcoming number of the *Annals* of the Observatory. A paper on "The Spectrum of β Lyræ," left nearly complete by Mr. Baxandall at his death, has now been prepared for press. Dr. F. S. Hogg kindly co-operated in this work. Other work of Mr. Baxandall's is also being prepared for publication.

A theoretical investigation into the mechanism of hydrogen emission in nebulæ will shortly be communicated to the Society by Dr. Carroll.

Total Solar Eclipse of 1929 *May* 9.—The Director and Dr. Carroll were absent for over four months, having gone to Pattani in Siam and to Alor Star in Kedah respectively to observe the total solar eclipse of May 9. Unfortunately weather conditions were entirely unfavourable at both stations. Details of the apparatus and programmes have already been communicated to the Society (*M.N.*, **90,** 121).

Meteorological Physics.—The study of the electrical fields associated with thunderstorms and showers has been continued. Further improvements have been made in the apparatus; in particular, an improved form of electrometer has been constructed. It is hoped that the new instrument will resolve further details in the records obtained during thunderstorms.

Dunsink Observatory.
(*Acting Director, Mr. Charles Martin.*)

The time-service to Dublin has been continued as in previous years.

During the past year the master clock of the General Post Office, Dublin, has been placed on the time-circuit, and controlled from the Observatory. The meridian circle has been used only for time determination.

The Observatory has been used mainly for teaching purposes, students being welcome in the daytime for instrumental instruction, and any clear evening for observational work.

Durham University Observatory.
(*Director, Mr. Harold Thomson, M.Sc.*)

The work on long-period variable stars has been continued with the Peek telescope.

Mr. Sargent has been able to make over 700 determinations of magnitude during the year, and has also made some observations on the surface markings of the planets.

In order to test the suitability of the site a Milne-Shaw seismograph has been erected in the house formerly occupied by the almucantar, which has been dismounted and stored. The results obtained up to the present appear to be satisfactory.

Imperial College Observatory, South Kensington.
(Assistant-Professor, H. Dingle.)

The usual courses of instruction of students in the observatory and laboratory have been carried out, and research in spectroscopy has continued during the year. Arrangements are being made for the more frequent use of the observatory for observation of prominences and occultations, and possibly other work. Professor Fowler attended the meeting of the British Association in South Africa in August, and gave two lectures on certain aspects of spectroscopy. Assistant-Professor Dingle, who began work as Secretary of the Society during the year, has delivered a course of lectures on practical applications of the spectroscope, including a certain amount of astronomical work. In addition to the following papers published during the year, Professor Fowler and Assistant-Professor Dingle contributed articles to the new edition of the *Encyclopædia Britannica*. Several spectroscopic problems are in course of investigation.

Professor A. Fowler: "The Arc Spectrum of Silicon" (*Proc. Roy. Soc.*, **123**, 422).

Dr. L. J. Freeman: "Further Investigation of the Spectrum of Ionised Nitrogen (*N* II.)" (*Proc. Roy. Soc.*, **124**, 654).

Mr. R. W. B. Pearse: "The Ultra-Violet Spectrum of Magnesium Hydride. I. The Band at λ2430" (*Proc. Roy. Soc.*, **122**, 442); "II. The Many-lined γ-System" (*Proc. Roy. Soc.*, **125**, 157).

Mr. K. R. Rao: "The Arc Spectrum of Germanium" (*Proc. Roy. Soc.*, **124**, 465); "Regularities in the Arc Spectrum of Arsenic" (*Proc. Roy. Soc.*, **125**, 239); "The Spectrum of Trebly-Ionised Thallium" (*Proc. Phys. Soc.*, **41**, 361); "Further Triplets of *As* IV." (*Nature*, **123**, 244).

Mr. E. W. H. Selwyn: "Arc Spectra in the Region λλ1600–2100" (*Proc. Phys. Soc.*, **41**, 392).

Messrs. A. S. M. Symons and J. Daley: "The Zeeman Effect for the Arc Spectrum of Gold" (*Proc. Phys. Soc.*, **41**, 431).

Mr. W. E. Pretty: "Pressure Shifts in the Spectrum of Ionised Nitrogen" (*Proc. Phys. Soc.*, **41**, 442).

Miss F. Lowater: "The Band Systems of Titanium Oxide" (*Proc. Phys. Soc.*, **41**, 557).

Liverpool Observatory and Tidal Institute.
(*Director, Prof. J. Proudman; Associate Director, Dr. A. T. Doodson.*)

Since 1929 January 1 the Liverpool Observatory of the Mersey Docks and Harbour Board and the Tidal Institute of the University of Liverpool have formed a single institution known as the Liverpool Observatory and Tidal Institute.

The chief addition to the equipment has consisted in the acquisition of the tide-predicting machine of the late firm of Edward Roberts & Co., tidal and astronomical computers. This machine was designed in 1906 by Mr. E. Roberts and built by A. Legé & Co. of London. It provides for 40 harmonic constituents, and is well known to those interested in tidal prediction.

For the testing of marine chronometers, a non-conducting chest has been fitted with electric lamps and a self-regulating device for maintaining constant temperatures.

Most of the instruments in the Observatory have been overhauled, tested, and in some instances improved.

The Molyneux clock, which has kept sidereal time, has been made to keep mean solar time, and has been moved into a more convenient position near a new wireless installation. This clock can now be used, when required, to fire the time-gun. The similar clock, also by Molyneux, which is normally used for firing the time-gun, was released for cleaning and repairs. The Bond sidereal clock has been repaired and transferred to a site near the normal gun-clock and associated wireless apparatus.

The Dines pressure-tube anemometer (recording wind direction as well as speed) has functioned very well. The seismometer has been rather troublesome, but most of its defects have been traced and remedied.

The expenditure on daily charts has been reduced by about 75 per cent. through having special blocks made, so that the charts can be printed locally, and through using the barograph charts again after each leap year.

A new system of recording the regular meteorological observations has been instituted in the form of a Weather Diary. In this all observations made on one day are entered on one page together with abstracts from the self-recording instruments at intervals of two hours, and means and totals. The same page also contains all the regular daily reports sent out.

The chief work of the Liverpool Observatory and Tidal Institute, however, is on tides. Predictions of high and low waters have been made for 61 places; of hourly heights for 2 places; and of times of slack water for 3 places. Eleven years' records from 6 places have been analysed. A study has been commenced of the distribution of the principal constituents of the tides in the English and Irish Channels with a view to constructing cotidal charts of these seas. Research has been carried out on the internal friction of certain tidal currents; also on a number of problems in the dynamical theory of the tides and of the effects on the sea of changes in atmospheric pressure.

University of London Observatory and University College Observatory.
(*Director, Professor L. N. G. Filon, F.R.S.*)

The new Observatory of the University of London at Mill Hill was opened by the Astronomer Royal on October 8.

The principal instruments are the Wilson 24-inch Reflector by Grubb, the 10-foot Rowland Grating spectrograph, and the cœlostat telescope of $7\frac{1}{2}$ inches aperture and 12-foot focal length. The latter is so designed that images of the sun and stars may be focussed on slits of fixed laboratory spectrographs by an automatic device which consists in setting two circles, namely, the one which moves the cœlostat in azimuth and reads declination directly, the other the hour-circle of the cœlostat. A slow-motion control is provided in both co-ordinates for purposes of guiding.

The observatory is provided with a well-equipped workshop, laboratory, dark room, and computing room.

Professor Filon has been appointed Director, and Mr. C. C. L. Gregory has been appointed Wilson Observer.

The Wilson telescope has been used on 44 nights and 26 plates have been taken, the greater number of these for the purpose of testing the capability of the instrument for various kinds of work. Some plates have been exposed " through the glass " on regions photographed with this instrument by the late Mr. W. E. Wilson in 1892 and 1893, in order to obtain data concerning the proper motions of faint stars. The performance of the instrument is very satisfactory : no vibrations from road traffic or strong wind have been detected.

Through the kindness of Professor Turner and others, the observatory has acquired a number of valuable star catalogues, etc.

The observatory has been open to members of the public on 6 afternoons since it was opened, and 256 visitors have inspected the instruments. Also on 5 nights the 6-inch guiding telescope of the Wilson telescope has been used by local residents, who have applied to the Director for permission to do so.

A short description of the observatory has been published by the University of London, and copies are being distributed to a number of observatories and Astronomical Societies.

At University College Observatory the work has been carried on as in previous years. A $3\frac{3}{4}$-inch equatorial refractor has been presented to this observatory by Messrs. Arthur and William Jaffé in memory of their father, the late Sir Otto Jaffé.

Radcliffe Observatory, Oxford.
(*Director, Dr. H. Knox-Shaw, Radcliffe Observer.*)

The great event of the year has been the decision of the Radcliffe Trustees to sell the Observatory site and to move the Observatory to South Africa. This project is still subject to the approval of the Charity Commissioners, but provided they do not object, the move

will take place in five years' time. The new site has not yet been finally selected, but Dr. W. H. Steavenson is proceeding to South Africa early in January to test sites on behalf of the Observatory.

It should be possible during the next five years, given average weather conditions, substantially to complete the proper motion programme in the Kapteyn Areas. It will be arranged, at any rate, that one plate is obtained of each area, though the congestion of plates yet to be taken in the winter months makes it unlikely that duplicate plates will be obtained of all the areas. Future progress will depend largely on the weather experienced during December, January, and February. This is never good here, and has perhaps been worse lately than usual, the *total* number of nights during these three months in the last five years, on which plates have been obtained, being 18, an average of only a little more than one a month.

During the year 29 plates were exposed on the Selected Areas, of which 16 have been passed for measurement. Fourteen other plates were taken, of which 8 were for testing the magnitude equation, and 5 were taken through colour screens of some of the Cambridge proper motion regions, at the request of Professor Eddington. Ten plates of the regular programme and 4 magnitude-equation plates were measured, and the reduction of five areas completed. In one of these over a thousand stars were measured. Preliminary survey work was done on 25 plates.

Steady progress has been made on the reduction of Hornsby's observations. That of the declinations for the whole period, 1774 to 1798, is nearing completion, and the coming year should see the publication of some definitive results. A paper in the form of a progress report on the work was communicated to the British Association at its meeting in South Africa.

University Observatory, Oxford.
(Director, Professor H. H. Turner, F.R.S.)

The new buildings (four rooms above ground and the "Crombie Basement" for the seismographs) are already proving a great increase in comfort and convenience, though their occupation has been delayed by their slowness in drying, in spite of the dry summer. The pier for the seismographs is scarcely yet steady enough for them; the E.W. component (the less steady of the pair) has been mounted on a temporary pier on the floor, with fairly satisfactory results.

The Vatican portion of the Astrographic Catalogue being now completely printed, Mr. Bellamy has spent much time since July last in the critical examination of the reference stars, for suspected cases of proper motion, variability, etc., as well as the detection of occasional errors.

Zone -22° of the Astrographic Catalogue has been photographed twice, once at Hyderabad in the northern hemisphere, once at the Cape of Good Hope in the southern. The former series of plates has been

completely measured and published by the Hyderabad Observatory; of the latter, measures for 0^h-18^h R.A. have been made at Oxford, and a comparison of the two will presently be made for the study of seasonal effects (which would suffer reversal in opposite hemispheres), if any.

Dr. Fotheringham (Honorary Assistant) has published an article on the "Calendar" in the *Nautical Almanac* for 1931; and an article on "Ancient Eclipses" in the *Encyclopædia Britannica*, 14th ed., 1929 (vol. vii., pp. 912–14).

The International Seismological Summary has been published regularly; the work of preparing it naturally tends to increase, but the interval of three years behind present date for the completion of the MS. has been maintained. It seems almost impossible to diminish it, owing to the tardy delivery of results for collation.

The Director has spent much time on the study of periodicities near 21 minutes shown by the long series of records of earthquakes in the Philippines (1890–1926). There appear to be three close together, like three close lines in a spectrum, periods about 20·99320, 20·99306, and 20·99256 min. It will readily be understood that a good deal of work had to be scrapped on the way to the elucidation of this result.

The origin of the corrosion in the brass screws of the astrographic telescope has at last been explained by Professor Sir H. C. H. Carpenter. There is apparently a phenomenon called "season-cracking," which is of common occurrence in brass and certain other copper alloys. "The phenomenon has attracted a good deal of attention during the last twenty years, and particularly since the war, but it would probably not have been suspected at the time the telescope was made. . . . No alloy cracks in this way unless it is in a condition of stress. It is now possible to obviate this phenomenon by a particular kind of heat treatment, and there need be no cracking in any brass screws made for telescopes to-day."

The (visual) object-glass of the guiding telescope was tested by Dr. Steavenson during a recent visit to Oxford and found highly satisfactory since its refiguring by Messrs. T. Cooke & Sons in 1923.

Norman Lockyer Observatory, Salcombe Hill, Sidmouth.
(*Director, William J. S. Lockyer, M.A., Ph.D., Major* (*late R.A.F.*).)

The 9-inch Kensington prismatic camera has been in regular use throughout the year for the purpose of photographing the spectra of stars showing bright hydrogen lines. The Zeiss triplet lens attached to this instrument has also been used regularly, chiefly for the photography of star regions, and occasional photographs have been taken with the fixed meteor camera. The 12-inch McClean prismatic camera has been in use during a considerable part of the year. It has been mainly employed for the routine photography of spectra of B-type stars, and occasionally for special stars or nebulæ.

The number of fine nights during the year was 141, on 132 of which

successful observations were made. This is above the average annual number of fine nights, and is better than in any year since 1926. The numbers of negatives secured with the various instruments were: 195 with the 9-inch prismatic camera, 35 with the Zeiss triplet, 18 with the meteor camera, and 144 with the McClean 12-inch prismatic camera.

Through the generosity of Dr. Robert Mond an equatorial mounting is being made for the Observatory by Messrs. Cooke, Troughton & Simms, Ltd., to carry various photographic lenses recently purchased by the Council, together with a suitable dome to house the instrument when completed.

Work has been continued on bright hydrogen-line stars, and on spectroscopic parallaxes. A further list of parallaxes of B-type stars is nearing completion, and also a note on peculiarities in stars of this type.

The number of visitors during the year was 259.

The thirteenth annual general meeting of the Norman Lockyer Observatory Corporation was held in London on June 13.

Stonyhurst College Observatory.
(*Director, Rev. E. D. O'Connor, S.J.*)

We are pleased to welcome Father Macklin back on the staff of the Observatory.

The meteorological, magnetic, and seismological records have been carried on as usual, and the results forwarded to the official centres. Absolute measures of the horizontal magnetic force and the inclination have been made once each month, and the declination observed each week.

The new Dines Pressure-tube Anemometer mentioned in last year's report was put into regular use as from May 1; it is working very satisfactorily. The highest gust registered in 1929 was 68 m/h on December 5.

The work on synoptic meteorology has been continued. The wireless installation has been replaced by a more elaborate one designed by the National Physical Laboratory. This, together with the separate L.F. amplifier used, employs in all nine valves, and operates a Creed undulator for the automatic recording of signals. This greatly facilitates the work of preparing synoptic charts.

Observations of the solar surface were made on 266 days and include 272 drawings. Of these 230 are complete, showing all spots and faculæ. Of the remaining 42, 17 are complete for spots. The mean daily spotted area (in units $\frac{1}{500}$ of the disc) works out at 6·19 as compared with 7·19 in 1928 and 5·15 in 1927.

Sunspot statistics have been sent regularly to Professor Brunner of Zurich for the preparation of the "Sunspot Numbers," published in the quarterly *Bulletin* under the auspices of the I.A.U.

Ten observations of occultation of stars by the moon and four of reappearances were made; as also an occultation, 1st and 2nd contact, of Venus. The results have been sent to Dr. Comrie.

At the request of Father Hagen of the Vatican Observatory, visual observations have been made, with the 15-inch equatorial, of Baxendell's Nebulosity N.G.C. 7088; likewise of the nebulosity about ϵ Orionis. Using a power of 50, and with a field of 42′ diameter, there appeared to be no doubt of the objectivity of these nebulosities. A systematic survey of the Herschel Fields has been started.

Dominion Observatory, Ottawa, Canada.
(*Director, Mr. R. Meldrum Stewart.*)

Meridian Work and Time-Service.—The meridian circle was in use throughout the year on the regular programme. There were obtained 2291 observations of stars, 63 of planets, 135 of the sun, and 121 clock corrections, on 192 observing days. The time-service was maintained as in previous years without material change. Wireless time-signals were received from Rugby, Annapolis, Bordeaux, and Nauen, the reception being made regularly by coincidence, by extinction, and, when convenient, also by registration. Time-signals were broadcast daily at 3 p.m., except Sundays, through radio station CNRO on concert wave-length, and daily through the observatory station on 40·8 metres.

Solar Physics.—The spectroscopic observation of points on the solar disc with iodine standard absorption spectrum at $\lambda 5600$ was continued, some 300 photographs being made. About 500 measurements of spectrograms with as many computations were made. About 100 direct photographs of the 9-inch solar image were taken, and copies supplied to the Radio Branch of the Department of Marine for investigation of sunspot influence on radio reception. Measurements of photographs of a number of tree sections were made, revealing the sunspot cycle in the widths of the annual growth-rings. The graduated sphere and co-ordinate frame for reading directly the heliographic positions of observed points was completed, and tests showed a sufficient degree of accuracy for this computation-saving method.

The 15-Inch Equatorial.—Radial velocity work was continued on bright Cepheids, on ϵ Aurigæ, and on η Virginis, which proved to be an interesting triple system. In all, 141 spectrograms were obtained. Curves of variation of ionisation and band intensity were obtained from an analysis of spectrograms of α Ursæ Minoris, microphotograms having been obtained with a Moll thermopile instrument. Further experimental work was carried on with the photo-electric photometer, and a number of all-night series of observations of β Cephei referred to α Cephei were secured. The telescope was, as usual, made available to visitors every clear Saturday evening.

Photographic Photometry.—On the original programme of Cepheid variables, magnitudes of comparison stars were measured and listed for 16 fields; measurements of the magnitudes of SU Draconis, RS Bootis, SZ Aquilæ, RV Ursæ Majoris, TT Aquilæ, RS Cassiopeiæ, SW Draconis, Y Lacertæ, and X Lacertæ were made on some four hundred plates. Observations on the new programme of fields selected by the inter-

national committee were begun in July. Magnitudes of comparison stars for these fields are to be determined at Harvard and at Ottawa. Sets of charts of 32 of the fields, for distribution to co-operating observatories, were prepared and forwarded to Harvard, where selection of the comparison stars will be made.

Seismology.—During the year 435 earthquakes were registered, of which 42 were reported to the Press and by telegraph to Science Service at Washington, D.C. The major disturbances were: Aleutian Islands, March 7; New Zealand, June 16; Aleutian Islands, July 5; Aleutian Islands, July 7; Alaska, September 17; North Atlantic Ocean, November 18; Aleutian Islands, December 17. The North Atlantic earthquake of November 18, located south of Newfoundland, is being made the subject of a special investigation. The seismographs at Ottawa, Saskatoon, Halifax, Shawinigan Falls, and Seven Falls were in practically continuous operation throughout the year. The *Bibliographical Bulletin* of the Eastern Section of the Seismological Society of America, previously edited at this observatory, has now been taken over as one of its regular publications, under the name *Bibliography of Seismology.*

Terrestrial Magnetism.—Observations were made at 10 stations along the water route between Sioux Lookout and James Bay by way of Lac Seul and Root and Albany rivers. Of these, three are exact and three approximate reoccupations of stations established by the Carnegie Institution in 1913, while three of the remaining four are new. Observations were also made in conjunction with gravitational surveys carried out with the torsion balance in the vicinity of two known faults near Ottawa.

Gravity.—A redetermination of the relative values of gravity at Ottawa and Washington was made during the early part of the year; a series of observations was also made to determine the temperature coefficients of the three pendulums of the pendulum apparatus. This work, together with the observations at Greenwich, Potsdam, and Ottawa, reported last year, completes what should be a fairly rigorous connection of gravity values in Europe and North America. The value obtained for Greenwich agrees well with that of earlier determinations, but the values for Ottawa and Washington are slightly higher than the previously accepted values. Considerable progress was made with computations of the unpublished work of 1927 which involves some fifteen field determinations. In co-operation with the Geological Survey, torsion balance surveys were made of certain geological structures (faults) in the vicinity of Ottawa. This work represents the beginning of an investigation undertaken for the purpose of ascertaining the applicability of the torsion balance to mining in Canada.

Publications.—Five of the regular series of publications (vol. 7, No. 4, *Seismology—The Location of Epicentres*, 1923–4–5; vol. 8, No. 9, *Gravity in Western Canada*; vol. 9, No. 6, *The Castor System*; vol. 9, No. 7, *A Study of Eta Aquilæ* (second paper); vol. 10, No. 1, *Bibliography of Seismology*) were published during the year. A number of articles by members of the staff appeared in various publications.

Dominion Astrophysical Observatory, Victoria, B.C.
(Director, Dr. J. S. Plaskett, F.R.S.)

Mr. R. O. Redman, who had been temporarily employed as research assistant for the previous year, was appointed to the permanent staff as astronomer last August. Professor A. Pannekoek of Amsterdam spent six months at the Observatory, obtaining high dispersion spectra of Cepheids and other stars for photometric study at Amsterdam. Mr. P. M. Millman was again appointed as student assistant, but owing to illness only remained for a month. Otherwise the staff remained as previously reported.

The observing weather for 1929 has been much above the average. On 226 nights 1224 spectra were obtained as compared with an eleven-year average of 1558 spectra on 207 nights. The smaller number of spectra secured is due mainly to the fact that on 67 nights an average per night of only two spectra of high dispersion or of very faint stars was obtained. A better comparison of observing conditions is given by the number of hours—1487 last year as compared with the eleven-year average of 1259. A total of 1531 spectra were measured, mainly for radial velocities, during the year. The Saturday open nights have been continued, at which the attendance and interest are well maintained. Including the day visitors, it is estimated that 39,000 persons visited the observatory during the past year.

The director and Mr. J. A. Pearce have completed jointly the observation and measurement of the radial velocities of all B0 to B5 stars brighter than 7·5 vis. mag. and north of dec. − 11°, some 450 in number, which had not been previously observed. The completion of these velocities, under way since 1924, has enabled progress to be made in their discussion, and preliminary solutions for the rotation of the galaxy have been made from the radial velocities of 850 O to B5 stars, and presented at two scientific meetings. These results, particularly for the more distant of these stars, strongly confirm the hypothesis of a differential rotation of the galactic system, and show that the excess positive residual, the mysterious K term of about 5 km. per sec. found by Campbell and others for the brighter B-type stars, entirely disappears for these stars which are of fainter magnitude than 5·5. An analysis of the motions of the diffuse matter in interstellar space, these motions being obtained from the displacements of the "interstellar" Ca^+ lines, H and K, in 260 of these stars, resulted in a velocity of the sun exactly the same as from the naked-eye stars. These cloud velocities follow even more closely than the stars the double wave swing produced by the galactic rotation, and the relative values of the rotational term for stars and clouds, almost exactly as two to one, show that, at least to distances in the galactic plane of 2000 parsecs, this diffuse matter is uniformly distributed. A catalogue of the radial velocities of nearly 1000 O to B5 stars, and of the interstellar clouds in the direction of over 260 of these stars, is nearly completed. The proper motions of nearly 80 per cent. of these stars will also soon be rendered available by the kindness of the director of

the Dudley Observatory. A discussion of the combined data should give important information in regard to the solar motion, the galactic rotation, the mean parallax, and the absolute magnitude of this interesting group of high temperature stars.

Mr. W. E. Harper has continued observation of the programme of A-type stars for the determination of absolute magnitudes. About 100 new stars were added to the list during the year, 400 spectra in all being obtained, so that the total number of A-type stars now available for the determination of absolute magnitudes is about 1100. Many stars, however, especially those in the winter section of the sky, are represented only by a single plate, and more are required for a satisfactory result. A few binaries were followed during the year, and additional plates made of binaries whose orbits had been previously determined, with a view to improving the periods. All told, 486 A-type spectra have been measured for radial velocity during the year.

Dr. C. S. Beals has completed the observation, measurement, and discussion of all the Wolf-Rayet stars within reach at Victoria, both in the ordinary and red regions of their spectra, and with the help of objective prism spectra of some southern Wolf-Rayet stars, kindly loaned from the Harvard collection by Dr. Shapley, has developed a method of classification of these peculiar spectra, uniform with the Henry Draper system. A theory to account for the broad band emission of the Wolf-Rayet spectra has been developed which ascribes these bands with the absorption frequently present at their violet edges to the continual emission from the star (probably on account of radiation-pressure) of gaseous particles at very high velocity. The mechanism is analogous to that now generally assigned as the cause of similar emission in the novæ. Calculation of the loss of mass due to this constant outflow allows a length of life to the star of the right order to explain the frequency of these objects. Considerable time has also been spent in developing methods of stellar spectro-photometry.

Mr. R. O. Redman has further observed spectroscopically the eclipsing variable Y Cygni, and several least-squares solutions have given a fairly definite determination of the progression of the apse over a period of nine years. Further solutions, using reliable values obtained for some of the elements from the light curves, should give an accurate value of this progression with its important implications. Mr. Redman has continued the determination of the radial velocities of over 200 Ko to K5 giants between 7·0 and 7·5 vis. mag. and within 20° of the galactic plane. Solutions for solar motion, galactic rotation, and K term have shown the solar motion little different from the usual value and a rotational term of about 4 km. per sec., corresponding to a distance of about 250 parsecs. The random or peculiar velocities of these K-type stars are high.

Mr. S. N. Hill has assisted in the computation and tabular work required in the discussion of the B-type velocities and has completed the determination of the orbit of H. D. 32990, an interesting and difficult spectroscopic binary also observed at Mt. Wilson.

There have appeared and been distributed during the year *Publica-*

tions, vol. 4, Nos. 12 to 14, while Nos. 15 to 17 are in press with others in preparation. Several articles in astronomical periodicals have also appeared during the year. The weekly meetings, or seminars, of the staff, a very useful feature of the work, have been successfully continued. Fifty of these meetings, usually on Friday afternoons, have been held during the year, when important outside contributions have been discussed and our own work thoroughly reviewed.

Helwan Observatory, Ministry of Public Works, Egypt.
(*Director, Mr. P. A. Curry.*)

Time Service.—The time service was maintained as usual; the error of the standard clock, Shortt No. 1, has been determined daily from the Bordeaux and Rugby rhythmic wireless signals. The clock has run well throughout the year without any attention. Its losing rate was steady up to the end of February when it increased fairly rapidly until the end of May, after which it remained steady until the middle of October when it began to decrease. The average change of rate throughout the year was $0{\cdot}001^s$ a day, the greatest change being in May when it was $0{\cdot}003^s$ a day.

There is a double wall to the clock room, but no other means are employed to control the temperature.

A reversible transit circle fitted with an impersonal micrometer was erected during July, in the same place as the old one. The instrument has been purchased from the Royal Observatory, Greenwich, and a full description of it is given in pp. 6–7 of the Greenwich publication, *Determinations of Longitude*. A number of observations have been taken since with satisfactory results.

Reynolds Reflector.—The telescope was used on 41 nights and 41 plates were exposed, 5 test plates, 2 in search of Comet Forbes, 3 on Comet Neujmin (1926), and 31 plates on nebulæ. Good images of Comet Neujmin were obtained and the positions computed.

General.—The usual meteorological, magnetic, seismological, and solar radiation observations were made.

The programme of daily ozone spectrograms was completed during the year and the instrument returned to Dr. G. M. B. Dobson.

Nizamiah Observatory, Hyderabad.
(*Director, Mr. T. P. Bhaskaran, M.A.*)

Astrograph.—The programme of work with this telescope remained the same as in previous years. The number of photographs obtained during the year was 124, most of which were in the regions of the old Potsdam zones. 154 plates have been measured for the Catalogue, besides 14 repetition plates in the Hyderabad zones which were taken for the determination of P.M.

The proofs of vol. vii. of the Hyderabad Astrographic Catalogue have

been passed for press, with the exception of the Introduction. It is hoped the volume will be ready for distribution early in 1930.

The Grubb Telescope.—The work on long-period variables has been continued, and 1301 estimates of visual magnitudes were obtained during the year.

Observations of some of Herschel's nebulosities have also been made with this telescope.

Forty occultations of stars by the Moon were observed:

Disappearances	34
Reappearances	6

Time.—Occasional observations with the transit instrument have been continued for the determination of clock corrections.

Seismology.—In March a new Milne-Shaw seismograph was erected, and since then both the machines have been in operation without much interruption. The readings of the seismograms are regularly forwarded to the University Observatory, Oxford.

Daily observations of the upper air by means of pilot balloon flights have been added to the routine meteorological work of the observatory in co-operation with the India Meteorological Department.

Kodaikánal Observatory.
(*Director, T. Royds, D.Sc.*)

Photoheliograms were obtained on 340 days, calcium flocculi plates on 335 days, calcium prominence plates on 298 days, and *Hα* flocculi plates on 295 days. On the whole, 2563 spectroheliograms were taken during the year. One calcium flocculi plate for each day was sent to the Solar Physics Observatory, Cambridge, as in former years.

Under the auspices of the International Astronomical Union, prominence and *Hα* spectroheliograms were collected from other observatories, whenever complete observations were not possible at Kodaikánal, and the combined results were published in the half-yearly bulletins. Copies of 117 spectroheliograms were supplied to the Meudon Observatory on request.

The taking of one prominence spectroheliogram in *Hα* light has been added to the daily programme of the observatory, and during the year prominence photographs in *Hα* light were obtained on 248 days.

Daily character figures for solar activity according to *Hα* bright flocculi and *Hα* dark markings have been communicated to the Observatoire Federal, Zürich.

An important part of the work during the year has been the monthly meetings of the staff, in which important contributions to solar physics appearing in the periodicals are reviewed.

Seismological and meteorological observations have been carried on as usual.

Wireless time-signals were regularly received from Colombo, Calcutta, and Rugby. Time-signals from Bordeaux were also received

for the first three months, but this was discontinued as they are received at an inconvenient time.

A quartz prism spectrograph with a sparking set by Adam Hilger, and a 10-foot concave grating spectrograph, the Eagle mounting of which was made in the observatory workshop, have been added to the equipment of the observatory.

In addition to the regular publications of the observatory, the following papers have been published during the year, or communicated for publication, by the staff of the observatory :—

(*a*) " On the Series Spectrum of *Tl* IV." (*Indian Journal of Physics*).
(*b*) " Further Regularities in the Spectrum of Doubly-Ionised Arsenic " (*Zeitschrift für Physik* and *Nature*).
(*c*) " On the Series Spectrum of Doubly-Ionised Lead " (*Zeitschrift für Physik*).
(*d*) " On the Structure of the Trebly-Ionised Spectrum of Lead " (*Zeitschrift für Physik*).
(*e*) " Variations in the Bases and Heights of Prominences."

The Director went on deputation to Pattani to observe the total solar eclipse of 1929 May 9, and he joined the British Eclipse Expedition. Observations of prominences, etc., were taken and cabled to Pattani on the 8th, in order to enable the Expedition to be prepared for any possible limb phenomena.

Observations with the Dobson spectrograph were continued till nearly the end of 1929 and the plates sent to Dr. Dobson.

The Director proceeded on leave for 5 months and 19 days from 1929 November 11, after officiating as Director-General of Observatories for 3 months.

Union Observatory, Johannesburg.
(*Union Astronomer, Mr. H. E. Wood, M.Sc.*)

26½-*Inch Grubb Visual Refractor.*—The double-star survey of the Southern Hemisphere is still in progress.

The year's work comprises :—

3177 measures of double stars (including the 9-inch measures),
583 new pairs discovered.

Observations of the satellites, Mimas and Enceladus, of Saturn were continued for Professor Georg Struve (Neubabelsberg). Observing conditions were not very favourable and only 22 measures of Mimas and 39 of Enceladus were obtained.

Some experimental work on double-star photography was carried out during the year and 29 plates, with multiple exposures, were taken of suitable double stars.

The year 1929, like 1928, was not a favourable one with respect to nights of good definition.

The formation of a card catalogue to include all measures of double stars south of − 19° is in progress.

Franklin-Adams Star Camera.—During the year 1218 plates were obtained with this instrument, distributed as follows :—

Minor planet regions and star maps . . .	255 plates.
Variable star regions	915 ,,
Comets	48 ,,

315 measured positions of minor planets have been forwarded to the Astronomisches Rechen-Institut.

Comet 1929*c* (Forbes) was observed photographically from 1929 August 3 to 1929 October 8. An unsuccessful search was made in October and December for Comet 1909 IV., which is expected to pass through perihelion in 1930 April.

Towards the end of the year an additional 10-inch photographic telescope was added to the Franklin-Adams mounting. The new lens, made by Messrs. Cooke, Troughton & Simms, Ltd., has a focal length of 92 inches and is mounted in a metal tube.

Mr. H. van Gent of the Leiden Observatory has continued to use the Franklin-Adams star camera throughout the year for the photographic investigation of variable stars.

Occultations of Stars by the Moon.—The programme of the last few years has been maintained. Predictions are made graphically for the disappearances, at about first quarter, of all stars in the moon's way for which positions are given in the A.G. Catalogues ; for those stars for which the elements are given in the *Nautical Almanac*, predictions are made by Dr. Comrie's semi-graphical process, and as far as possible the occultations of all such stars are observed.

During the year 1929 the number of occultations observed was 152. The results of the year's observations are as follows :—

	s	″
1929·1	10·6	5·8
·4	12·6	6·9
·6	11·2	6·1
·9	10·4	5·7

The second column indicates the time by which the moon has arrived too early at any longitude, and the third column the distance the moon is ahead of its tabular longitude.

Dr. J. Moir of Auckland Park, Johannesburg, who rendered valuable assistance in the observation of occultations, died on 1929 March 30.

Time Service.—Throughout the year, time has been taken from the rhythmic signals sent out from Rugby, England, at 10^h U.T.

9-*Inch Grubb Refractor.*—This telescope is now used mainly for observations of occultations of stars by the moon, eclipses of the satellites of Jupiter, and measures of the wider double stars. One night a week is set apart for visitors and, during 1929, 1677 visitors availed themselves of the privilege.

Union Observatory Circulars, etc.—During the year Circulars Nos. 78,

79, and 80 were issued, and the MSS. of Circular No. 81 was forwarded to the Government printer.

Of the Southern Star Maps, 47 were issued with these Circulars, and the present state of the project is therefore :—

Maps already issued	366
Maps in hands of Government printer	21
Maps still to be prepared	169
Total .	556

Miscellaneous.—During the meeting of the British Association in South Africa in 1929 July–August, about 200 of the members, including many astronomers, visited the Observatory. It is interesting to record that the telegram announcing the discovery of Comet 1929 *c* (Forbes) was received whilst a large party of the British Association members was at the Observatory and that the Astronomer Royal assisted in the confirmation of the discovery.

Melbourne Observatory.
(*Director, Dr. J. M. Baldwin, Government Astronomer.*)

The 8-inch transit circle has been in use throughout the year for observations of stars from the list of Fundamental Stars published in the *Connaissance des Temps* for 1914 which cross the meridian more than 20° above the horizon.

The final plates for the triple-exposure charts were taken with the astrographic telescope early in the year. As soon as there is opportunity, a photoelectric photometer, the working drawings for which have been prepared, will be constructed and used in conjunction with the astrographic telescope.

Volume III. of the Melbourne portion of the *Astrographic Catalogue*, containing the rectangular co-ordinates of stars on plates with centres along − 69° and − 70°, was received from the printer in December, and is being distributed.

2144 observations of southern variable stars of long period were made during the year, and have been forwarded for publication in *Popular Astronomy* with observations made by other members of the American Association of Variable Star Observers.

The volume of *Hourly Values of the Magnetic Elements at Toolangi in* 1927 has been printed and distributed, and seismological bulletins have been issued quarterly.

Sydney Observatory.
(*Director, Mr. James Nangle, Government Astronomer.*)

Unfortunately cloudy weather adversely affected work on the Astrographic Catalogue. The photography, transit observations, and reductions of computations of plate constants, together with the preparation

of the matter for printing of vols. i. to lii. of the great Astrographic Catalogue, form the main part of the programme at this observatory. The progress is necessarily slow because of the small staff employed, but the work is steadily progressing.

During the year the printing of vols. v. and vi. of the Astrographic Catalogue was completed, and copies of the volumes were issued to the principal scientific societies and observatories. Two more volumes are now ready for the printer, and it is hoped that these will be completed and distributed during 1930.

In the last report it was stated that the photography of the Catalogue plates had been completed, but that much work remained to be done before the photographing of the Chart plates would be completed. During 1929 the taking of plates was continued, though this also was interfered with by adverse weather conditions. It is hoped, however, to have the taking of plates completed by the end of 1930.

The Sydney Observatory is charged with the responsibility of providing all astronomical information necessary for civil purposes, including observations for time and its distribution by time ball and wireless signals, and consequently quite a large amount of routine work is carried on each year, and the volume of this kind of work continues to increase.

An important part of the programme is that which provides for general education of the public in astronomical science. To this end the observatory is open one night each week, and visitors under the direction of an assistant astronomer are allowed to see through the telescope, and when this is impossible, owing to bad weather, are given lectures illustrated with lantern slides. During 1929 the total number of visitors was 669.

Undergraduates of the Sydney University who are taking Astronomy in their Science Course are given demonstrations on the transit instrument and the 11½-inch equatorial refractor.

Observations for seismological disturbances were continued throughout the year. Ninety-seven tremors were recorded on the Milne seismograph. The principal disturbance was that of the New Zealand earthquake on June 16, which caused great destruction to several towns on the west coast of South Island, New Zealand.

The Staff consists of W. E. Raymond, First Assistant; W. C. Graham, Second Assistant; J. Short, Astronomical Photographer; and H. E. G. Rayner, Part-time Assistant.

The Dominion Observatory, Wellington, New Zealand.
(*For the Year* 1928.)
(*Director, Dr. C. E. Adams, Dominion Astronomer.*)

The time service has been maintained, and the regular signals have been sent out. The signals have been transmitted daily. The total number of time-signals sent from the Observatory was 1684.

The usual method of recording radio time-signals has been to use the

chronograph with a hand key. This method will be supplemented by an entirely automatic one, by means of the Marconi Magnetic Relay which is now being installed.

Wellington General Post-Office Clock.—The Post-Office clock is checked at 3 p.m. on Mondays, Tuesdays, Thursdays, and Fridays by the broadcast signal through station 2YA, Wellington. On Wednesdays, when station 2YA is not broadcasting, the clock is frequently checked by the signal heard through the air. This clock is not under the control of the Observatory. The greatest errors were 9 seconds slow on May 29, and 14 seconds fast on December 5.

Government Buildings Clock.—The Government Buildings clock has been kept under fairly close control. A record is obtained at the Observatory by direct circuit from the clock, and the adjusting weights on the pendulum are altered from time to time. The greatest errors of this clock were 53·0 seconds slow on March 28, and 27·6 seconds fast on June 2.

Summer Time.—The Summer Time Act, 1928, provided for the time in New Zealand being half an hour in advance of New Zealand standard time for the period beginning at 2 a.m., New Zealand standard time, on Sunday, 1928 October 14, and ending at 2 a.m., New Zealand standard time, on Sunday, 1929 March 17.

Seismology.—During the year 287 earthquakes were recorded on the seismographs. The total number of earthquake shocks felt in New Zealand was 80 : 60 of these were felt in the North Island and 23 in the South Island. In three cases the same shock was felt in both islands. In addition to the instrumental records of earthquakes, reports on all earthquakes felt are sent to the Observatory from a large number of observers.

Occultations.—With the assistance of members of the New Zealand Astronomical Society resident in different parts of the Dominion, arrangements have been made for observations of the occultations of stars by the moon, and the results of the observations have been sent to Dr. L. J. Comrie, *Nautical Almanac* Office, London.

The largest refractors in use in New Zealand are the 9½-inch visual refractor at Wanganui, and the 9-inch photo-visual refractor at Wellington.

Site Testing.—Extensive observations for site testing were undertaken in a number of localities chiefly in the South Island, and the detailed results were published in the *Journal of the British Astronomical Association*, vol. **39,** No. 6, 1929 March.

The observations showed that in a number of these places the conditions are almost perfect.

Publications.—The following Observatory publications have been issued during the year :—

Bulletin No. 68.—" Interpolation," by C. E. Adams.

Bulletin No. 69.—" International Longitude Determinations, 1926."

Bulletin No. 70.—" Reception of Wireless Time-Signals at the Dominion Observatory, Wellington."

Bulletin No. 71.—" Tables of Geodetic Factors for Use on the

Brunsviga Calculating Machine," by C. E. Adams. (Extract from the *Transactions of the Australasian Association for the Advancement of Science.*)

Bulletin No. 72.—"The Orbit of the Comet 1927*k*," by P. W. Glover. (Reprinted from the *Transactions of the New Zealand Institute*, vol. **59**, pt. 3, 1928 September.)

Bulletin No. 73.—"Earthquakes in New Zealand."

Bulletin No. 74.—"Solution of Euler's Equation in a Parabolic Orbit," by C. E. Adams. (Reprinted from *Astr. Nachr.*, Nr. 5617, Marz, 1929.)

Bulletin No. 75.—"Report of the Department of Scientific and Industrial Research."

Bulletin No. 76.—"New Zealand Time Service Arrangements."

E. 12.—Earthquake reports for 1927, February.

E. 13.—Earthquake reports for 1927, March to May.

E. 14.—Earthquake reports for 1927, June to August.

E. 15.—Earthquake reports for 1927, September to December.

As in past years, the Observatory is again indebted to individuals and to institutions for valuable gifts of publications. Some of these are presented in exchange for the *Bulletins*.

Mr. A. F. Bennett's Observatory, Leiston, Suffolk.

Observations of the disc and at the limb of the sun have continued as in previous years. The 6-inch Cooke equatorial has also been used for physical observations of the planets, on several long-period variable stars, and for some comet-searching. Comet 1929 *d* was seen in December, and measures for position obtained. Thirteen occultations of stars by the Moon and one by Mars have been observed during the year, under satisfactory conditions. These have been communicated from time to time to the B.A.A. and will be published in due course.

It was found necessary in September to readjust the setting of the 6-inch mounting, which had become deranged owing to slight subsidence of the concrete foundations. This was most probably caused by the exceptionally dry summer, as no sensible error in the adjustment had been apparent during the last seven years.

Rev. T. E. Espin's Observatory, Wolsingham.

The micrometrical measures and the search for new double stars have been carried on as in previous years, and the results communicated to the Society.

Mr. F. J. Hargreaves's Observatory, Kingswood, Surrey.

During the summer of 1929 a new equatorial mounting was completed to carry the 12¼-inch mirror lent by the Rev. T. E. R. Phillips. This

mounting also carries the 6½-inch mirror with which all former visual observations had been made, as well as two cameras with wide-aperture lenses of 20-inch focus and a 3-inch guide telescope. Both reflectors are in " skeleton " tubes. The driving clock is of the Gerrish type.

Observations of the physical features of Jupiter were continued until March 17, and resumed with the 12¼-inch reflector on July 18. The conditions since the latter date have, however, been exceptionally unfavourable, both as to the number of clear nights and the quality of the seeing.

Thirteen occultations of stars by the moon were observed during 1929, with the aid of a marine chronometer lent by the Hydrographer. The chronometer is rated by means of the Greenwich wireless time-signals. A stop-watch is used both for timing the occultations and for comparing the chronometer with the time-signals, and the run of the stop-watch is arranged to be approximately the same in the two cases, thereby eliminating as far as possible stop-watch errors and personal errors associated with its use.

In the autumn a beginning was made on an extensive programme for the photographic determination of effective wave-lengths of stars with the aid of a wire grating on the 12¼-inch reflector. This work has been very seriously hampered by the exceptionally bad weather and no useful results have yet been obtained. In order to reduce to some extent the difficulties caused by deterioration of the silver of the mirrors, the Newtonian flat will shortly be replaced by a reflecting prism of special construction.

Mr. A. M. Newbegin's Observatory, Worthing, Sussex.

Observations were made on 139 days, yielding 1855 prominences with a mean daily frequency of 13·34. Their distribution was uniform so far as east and west limbs are concerned, but 52·5 per cent. occurred in the southern hemisphere. There were, however, fluctuations in numbers between north and south from month to month, but for seven months the southern hemisphere continuously preponderated.

The mean daily frequency for the whole year is higher than might be expected, bearing in mind the distance we are from the last maximum, but from September to the end of the year a steady rise in frequency was recorded and December was remarkably abundant with 17·0 prominences per day.

Metallic activity was observed on 84 occasions, the distribution east and west being equal. This is a smaller number than in 1928, but there were more in Classes 2 and 3 than in that year. Displacements of the *Hα* line were recorded in 72 prominences, 39 being on the east limb and the remainder on the west : of these 46 were to the violet, 14 to the red, and 12 both ways simultaneously.

Many large prominences were observed, especially in the latter part of the year, and during this period the areas seem to have increased with the daily number. The largest prominence began on September

26 and lasted for three days, covering 38° of the limb and attaining a height of 120″.

Sunspots.—169 observations of sunspots were made, the mean daily frequency being 4·78. In September and October there was a marked decline in numbers, and at the beginning of the former month the sun was free of spots except for one very minute spot south of the equator. A revival set in in November and December, the latter month having the high mean daily frequency of 7·3. The year thus closed with a high peak of activity of an intensity equal to the two peaks of the previous year.

All the principal groups of spots have been observed spectroscopically, and details of the observations may be found in the quarterly summaries published in the *Journal of the B.A.A.*, **39** and **40.** In all, 18 groups were visible to the unaided eye.

Mr. B. M. Peek's Observatory, Solihull, Birmingham.

The adopted co-ordinates of the observatory as taken from the 1920 Ordnance Survey are

Long.	$7^m\ 9^s{\cdot}86$ W.
Lat.	52° 25′ 17″·7 N.
Altitude	130 metres.

Lunar occultations and physical observations of the major planets form the principal work of the observatory, Jupiter having claimed most attention during 1929. Close touch is kept with the Director of the Jupiter section of the B.A.A., to whom the results of all observations are communicated.

Seventeen occultations of stars by the moon were recorded during the year, and the reduction in duplicate of 28 occultations observed in 1928 has been completed. The results of the latter have been communicated to the Society and to Prof. E. W. Brown of Yale University.

Photometric observations of Nova Persei 1901 have been continued, and the magnitudes will be communicated in due course.

During August and the early part of September, observations were carried on with the 150 mm. Zeiss refractor at Herne, but at the close of this period the instrument was dismantled and transferred to Solihull, where its Dallmeyer mounting has now replaced the less suitable one which formerly carried the $12\frac{1}{4}$-inch mirror. An open lattice-work tube, modelled on that constructed and used by Mr. F. J. Hargreaves, has been made for this instrument, and the whole is now performing very satisfactorily. It is intended to mount with it the two astro-cameras, when the whole outfit should be very compact and complete; but before adding the extra weight it seems desirable to fit a roller bearing for the upper end of the polar axis to avoid placing undue strain on the driving worm; it is hoped that this will be available shortly, when attention will be directed to the substitution of a "Gerrish" drive for the existing clockwork.

Rev. T. E. R. Phillips's Observatory, Headley, near Epsom, Surrey.

The usual routine work has been continued.

A number of double stars have been measured with the 8-inch equatorial refractor lent by the Society, and some long-period variable stars which are very faint at minimum have been observed with the 18-inch reflector belonging to the British Astronomical Association. In addition several other variable stars were observed by Mr. P. M. Ryves, who was in England during a portion of the summer.

The 18-inch and 8-inch telescopes have also been employed for observations of Jupiter. Although during the recent apparition the state of the planet's surface has been much less disturbed than at the 1928 presentation, there has been one feature of very special interest and importance to which Mr. A. S. Williams was the first to draw attention, viz. an outbreak of rapidly moving spots (rotation period $= 9^h\ 49^m \pm$) at the S. edge of the N. temperate belt similar to those which appeared in the same latitude in 1880 and 1891 92. Another interesting feature of the apparition has been the reappearance of what seems to be the old S. Tropical Disturbance.

On the whole, the seeing conditions in 1929 were very unfavourable. During the long-continued fine weather the sky frequently clouded over about midnight, while in striking contrast with what was experienced in 1928 definition was usually very bad.

The Twenty-fourth Report of the Jupiter Section of the British Astronomical Association, dealing with the apparitions of 1922, 1923, and 1924, was prepared and published during the year.

The meteorological observations have been continued. Without going into the details of a very remarkable year, it may be mentioned that whereas at the end of September the total rainfall was only 10·35 inches, by the end of December it had been increased to 30·96 inches, which is but little short of the normal yearly value.

Dr. W. H. Steavenson's Observatory, West Norwood.

Observations were made on 101 nights during the year. Included in this number are 25 nights on which work was done away from West Norwood—12 at the Royal Observatory, Greenwich, and 13 at certain observatories in the United States.

100 photometric observations of faint novæ were made during the year, chiefly with the 6-inch Wray refractor.

Wilk's comet was observed for position on three nights at the end of December.

Mr. H. G. Tomkins's Observatory, Dedham, Essex.

The work of this observatory has been continued during the year. The 24-inch Cassegrain reflector has been improved by a change in the

arrangements for focussing, which was formerly done on the camera at the lower end of the tube, and later also by a fine motion on the convex mirror at the upper end. After considerable trial the latter method has now been adopted, and by means of a very accurately cut gear the necessary fine motion of the convex has been secured. It is worked from the camera end by a rod running in ball-bearings, up the length of the tube. This secures a theoretical movement at the focal image of about $\frac{1}{560}$ of an inch, which is ample for the purpose and has resulted in a satisfactory improvement in definition.

The trial camera hitherto used, having now served its purpose of experiment, will shortly be replaced by one of aluminium. This is nearly completed in the workshop, and is expected to be a considerable improvement on the old one, especially as regards rigidity. It is made entirely of aluminium, and will take either full or half-size plates. Provision has also been made for the use of light filters. A subsidiary mirror and apparatus, as used at Yerkes by Professor Ritchey, is being provided to watch the image of the moon up to the moment of exposure of the plate.

A trial was made with an open tube for the telescope, but this had to be abandoned for photographic lunar work on account of dust and stray light interfering with the plate film.

The mirrors were re-silvered during the year, and the smaller sizes were done face down in the solution. For those who prefer this, on account of its simplicity, to the face-up method, it may be mentioned that " Barnacle " holders, such as are used for licences on the windscreens of motor cars, are excellent for safely holding the mirror by its back, instead of pitch, etc., and make the operation more simple, certain, and expeditious than the other method.

Forty-five photographs of the lunar surface have been obtained since the last report, making 91 altogether. Many of these have been examined, including those of the M. Nectaris referred to last year, and three features hitherto unrecorded were reported to the Society in a paper on 1929 December 13. Indications of other less extensive features have also been found on the plates, as well as some small local peculiarities near particular craters and probably connected in some way with them. The plates taken under high illuminations of the lunar surface are many of them studded with what are probably minute craterlets, which sometimes occur on the surface in long lines. Two of these lines lie approximately parallel across the southern part of the M. Serenitatis, but there are also others. The examination of these is a laborious task, and the result will be reported later on.

The plates used are the Ilford Astra, which have the advantage of a fine grain, and give excellent contrast.

Cloudy skies and high winds have greatly hindered the work in the Observatory, but have of course set free more time for the examination and comparison of the plates already taken, as well as the construction of necessary apparatus in the workshop.

Notes on some Points connected with the Recent Progress of Astronomy.

Discovery of Minor Planets in 1929.

One hundred and fifty planets were discovered in 1929, as follows :—

Month and Designation.	Day of Month.	Magnitude.	Discoverer.
Jan.			
AA	8	13·0	SW
AB	1	14·0	R
AC	11	13·5	R
AE	12	13·5	R
AF	12	14·0	R
AG	8	13·0	S.W
AJ	13	..	A
AK	13	13·0	D1
AL	11	13	B1
AM	14	13·5	D1
BA	16	13·9	R
BB	16	13·8	R
BC	16	14	R
BD	29	14·1	R
BE	29	14·0	R
BF	29	14·0	R
BG	31	12·8	R
Feb.			
CA	3	13·2	B2
CB	3	13·0	B2
CC	3	12·8	B2
CD	4	13·0	A
CE	9	12·0	A
CG	8	14·0	A
CH	1	14	R
CJ	1	14·0	R
CK	2	15·0	R
CL	2	13·6	R
CM	2	14·0	R
CN	2	14·7	R
CO	2	15·0	R
CP	3	15·0	R
CQ	3	14·2	R
CR	3	15·0	R
CS	4	14·2	R
CT	4	15·0	R
CU	7	13·8	R
CW	7	13·8	R
CX	7	14·0	R
CY	7	14	R
CZ	12	13·5	B2
Feb.			
CA1	7	13·9	R
CB1	7	13·7	R
CC1	8	13·9	R
CD1	8	14·0	R
CE1	9	15·0	R
CF1	9	14·5	R
CG1	11	14·2	R
DA	28	14·2	A
DB	28	14	A
Mar.			
EA	10	13·5	D1
EB	10	13·5	D1
EC	3	12·9	A
ED	12	14	R
EE	12	14·0	R
EF	12	14	R
EG	12	15·0	R
EH	12	13·7	R
FA	18	13·3	A
FB	16	12·5	R
Apr.			
GA	3	13·6	R
GB	8	..	D1
GC	11	14·0	J
GD	5	13	J
GE	11	14	J
May			
JA	10	14	R
JB	10	14	R
JC	3	13·2	N
JD	13	14	R
JE	9	13·7	N
JF	9	12·0	N
JG	10	14	N
KA	31	13·2	R
June			
LA	7	13·7	N
LB	7	13·6	N
LC	7	13·4	N
LD	7	13·7	N
June			
LE	11	13·5	N
LF	11	12·5	N
LG	8	13·5	N
LH	13	13·0	J
MA	27	13·8	J
July			
NA	5	12·9	D2
NB	6	13·0	P
NC	2	14·0	J
Aug.			
PA	4	14·5	W
PB	4	15·0	W
PC	4	15·5	W
PD	10	15·0	W
PE	13	15·5	W
PF	1	13·2	S1
PG	5	14	N
PH	8	13·4	P
PJ	6	..	W
PK	12	15·0	KB
PL	1	14·0	J
PM	6	13·7	J
QB	31	14	R
QC	31	13·7	R
QD	30	13·5	N
QE	30	13·5	N
QF	31	13·3	N
QG	31	13·0	N
Sept.			
RA	1	14	R
RB	2	13·9	R
RC	2	12·6	R
RD	2	13·9	R
RE	2	14·0	R
RF	5	13·7	R
RG	5	13·5	R
RH	7	14	R
RJ	8	14	R
RK	8	13·7	R
RL	8	13·7	R
Sept.			
RO	10	13·6	R
RP	9	14·5	W
RQ	1	13·5	N
RR	1	13·7	N
RS	1	13·2	N
RT	3	13·8	N
RU	9	13·9	R
RV	4	13·8	N
RW	5	13·5	N
RX	13	13·7	N
SA	25	13·5	R
SB	26	13·7	R
SC	27	13·8	R
SD	27	13·7	R
SF	28	14	R
Oct.			
TA	3	12·8	N
UA	30	12·9	S2
UB	30	13·0	G
Nov.			
VA	9	15	W
VB	1	14	N
VC	1	14	N
VD	2	14·5	N
VE	2	14	N
VF	7	14	N
VG	6	12·3	B1
WA	21	15	R
WB	21	13·3	R
WC	21	15	R
WD	21	14	R
WE	21	14	R
WF	22	13·9	R
WG	28	13·0	S2
Dec.			
XA	1	12·7	S2
XB	6	13·7	R
XC	6	13	R
XD	2	13·6	N
YA	19	11	W

1929 WB was subsequently found on a plate exposed at Simeis on 1929 October 8.

The initials stand for: A = S. Arend, Uccle; B1 = S. Beljawsky, Simeis; B2 = P. Bourgeois, Uccle; D1 = E. Delporte, Uccle; D2 = A. Deutsch, Simeis; G = E. Gastardi, Madrid; J = C. Jackson, Johannesburg; KB = J. Krieger and N. Bobrovnikoff, Lick; N = G. Neujmin, Simeis; P = P. Parchomenko, Simeis; R = K. Reinmuth, Königstuhl; SW = A. Schwassmann and A. Wachmann, Bergedorf; S1 = E. Skvortzoff, Simeis; S2 = J. Comas Sola, Fabra, Barcelona; W = M. Wolf, Königstuhl.

The following identities have been established: 232 = 1929 QA, 464 = 1912 PB = 1912 PC = 1916 Σ22 = 1929 AH, 491 = 1928 DA1, 629 = 1929 AD, 661 = 1929 CF, 684 = 1928 PB, 805 = 1928 QG, 806 = 1929 SE, 811 = 1928 DB1, 954 = 1905 RW, 970 = 1929 RN, 982 = 1928 QF, 1053 = 1929 RM, 1059 = Σ111, 1068 = 1929 CV, 1082 = Σ64 (probably = 1916 ZU), 1084 = 1927 JB = 1928 TA, 1089 = 1894 BD, 1092 = 1924 PN, 1094 = 1918 DJ = Σ154 = 1926 CB, 1098 = 1906 VE = 1926 EC, 1100 = 1918 EK, 1906 WA = 1928 WA, 1908 BP = 1929 GD, 1927 CO = 1929 QG.

The following identities are more or less probable: 672 = 1929 XB, 836 = 1929 SC, 963 = either 1929 BA or 1929 BB, 1924 PN = 1929 BE, 1929 PB = 1929 PD, 1929 TA = 1929 YA, 1929 VC = 1929 WD, 1922 MY = 1927 EA (B. Asplind). *L. O. Bull.*, No. 411, contains new elements of 1922 MY by C. J. Krieger and D. C. Dinar.

The following planets have received permanent numbers: 1926 CC = 1084, 1927 QH = 1085, 1927 QL = 1086, 1927 RD = 1087, 1927 WA = 1088, 1927 WB = 1089, 1928 DG = 1090, 1928 DT = 1091, 1924 PN = 1092, 1925 LA = 1093, 1926 CB = 1094, 1928 DC = 1095, 1928 OB = 1096, 1928 PC = 1097, 1928 RJ = 1098, 1928 RQ = 1099, 1928 SD = 1100, 1928 SI = 1101, 1928 VA = 1102, 1928 VB = 1103, 1928 XA = 1104, 1929 AB = 1105, 1929 CW = 1106, 1929 FB = 1107, 1929 KA = 1108, 1929 CU = 1109, 1928 PD = 1110, 1928 WA = 1114, 1928 QC = 1113.

The following planets have been named: 951 *Gaspra*, 952 *Caia*, 959 *Arne*, 960 *Birgit*, 961 *Gunnie*, 1008 *La Paz*, 1039 *Sonneberga*, 1065 *Amundsenia*, 1093 *Freda*, 1114 *Lorraine*.

1929 KA and 1929 SA were moving northward at the unusual rates of 25′ and 29′ daily; both have large eccentricities and inclinations, and small perihelion distances.

1908 BN (see *A.N.*, 5668) and 1929 CM appear to be of Hilda type, with n 427″·75 and 447″·7 respectively. 1929 RK was suspected to belong to the Trojan group.

No. 65 of the Publications of the Copenhagen Observatory contains formulæ for the approximate calculation of planetary or cometary perturbations, by B. Strömgren; they are illustrated by application to the planets 633, 956, 979, 1035, 1049.

Improved elements, or studies of the perturbations, of the following planets have been published (see also *Kleine Planeten*, Jahrgang 1930).

Planet.	Reference.	Planet.	Reference.	Planet.	Reference.
11	*A.N.*, 5672	814	*Proc. Imp. Ac. V.*, 1929, No. 2	1036	*A.N.*, 5678
122	*A.N.*, 5670	850	,, ,, ,,	1040	*J.O.*, **12**, 121
173	*J.O.*, **12**, 176	852	,, ,, ,,	1924TG	*A.N.*, 5670
315	*A.N.*, 5634	857	,, ,, ,,	1073 to 1091	*A.N.*, 5623
426	*J.O.*, **12**, 173	860	,, ,, ,,		
434	*A.N.*, 5654	940	*A.N.*, 5670		
703	*A.N.*, 5651	1019	*A.N.*, 5654		
737	*J.O.*, **12**, 122	1025	*A.N.*, 5654		

P. E. de la Villemarqué has computed the perturbations by Jupiter of planets with n between 1000″ and 1100″ in *J.O.*, **12**, 44, 72, 122, 162.

B. Thüring studies the perturbations of the Trojan group in *A.N.*, 5618. The new orbit of 1036 *Ganymede* has $n = 815''{\cdot}23$, ϕ 32° 37′ 15″·6, period $4^{y}{\cdot}3524$, q 1·2287. *L.O.B.*, No. 407, contains a study of the spectra of minor planets by N. T. Bobrovnikoff. Variations in the spectrum of Vesta lead to the conclusion that it rotates in $5^{h}\ 55^{m}$; this is confirmed by variations in magnitude.

As a rule the spectra are found to be weak in the violet and ultra-violet. The characteristic hump in the spectral intensity in stars of type Go (near the H and K lines) is generally flattened out in the minor planet spectra; it is stated that the spectra of cometary nuclei show the same phenomenon. It is suggested that iron and sulphur would give this type of spectrum.

Addendum.—An additional planet 1929 YC was found at Simeis on December 30 by N.; one named 1929 YB proved to be identical with 785. 1929 TA is not identical with 1929 YA. Images of 1929 TA and 1929 WB have been found on plates taken at Simeis in 1925 (*B.Z.*, No. 4).

A. C. D. C.

Report on Comets in 1929.

Two comets, discovered in previous years, were followed during 1929; Dr. W. Baade photographed 1925 II. (Schwassmann-Wachmann (1)) on 1929 December 2, when its magnitude was 13·5, and on December 5, when it was 14·5; it had evidently undergone a sudden increase of light, as on November 6 it was invisible (fainter than magnitude 17). The December observations were more than $4\frac{1}{2}$ years after perihelion passage. Comet 1927 IV. (Stearns) was observed by Professor G. van Biesbroeck at Yerkes throughout 1929; it was of magnitude 16 in December; it was then $2\frac{3}{4}$ years after perihelion passage, and the distance from the sun was 8·68 units.

The first discovery of 1929 (1929 *a*) was made at Bergedorf on January 17 by Professor Schwassmann and Dr. Wachmann; it was of magnitude 11·0 with a nucleus of magnitude 13·0; a later Bergedorf photograph with 2 hours' exposure showed a tail 2′ long. It was nearly

Ref. No.	Year and Number of Comet.	Name.	T.	ω.	Ω.	i.
153	1818 I.	Pons-Coggia-Winnecke-Forbes	Feb. 6·05	195 43 58	249 29 29	29 8 [illegible]
316	1873 VII.	,,	Dec. 1·95949	196 7 46	249 49 13	28 46 31
424	1896 V.	Giacobini (1)	Oct. 28·0313	140 31 45	193 25 34	11 21 43
486	1909 IV.	Daniel	Nov. 28·7313	3 29 3	70 59 48	19 26 58
506	1913 III.	Neujmin (1)	Aug. 16·43234	346 13 57	347 54 46	14 50 26
579	1927 VII.	Pons-Winnecke	June 21·07452	170 23 5	98 8 41	18 56 54
579	1927 VII.	,,	June 21·08333	170 21 50	98 10 8	18 56 46
584	1928 III.	Pons-Coggia-Winnecke-Forbes	Nov. 4·95184	195 52 30	250 3 59	28 53 50
585	1929 I.	Schwassmann-Wachmann (2)	Mar. 23·0387	357 38 28	126 4 30	3 43 47
586	1929 II.	Forbes	June 25·4941	258 46 4	25 47 21	4 36 20
587	1929 III.	Neujmin (3)	June 28·19222	140 30 58	158 13 52	3 41 6
..	1929	Giacobini (1)	P Sept. 24·75	142 25 41	192 34 15	11 52 47
..	1930	Wilk	Jan. 22·3056	157 31 1	179 2 27	124 30 10

T is in G.M.T. up to the end of 1924, in U.T. from 1925·0.
The letter P indicates predicted elements.

in opposition to the sun, and was discovered in the course of the search for minor planets; as the region opposite to the sun is photographed at many observatories, search was made for previous images of the comet; several were found, including 1928 December 8 and 19 (Oikawa, Tokyo), December 19 (Harvard), 1929 January 4 (Yerkes), January 9 (Harvard), January 12 (Uccle and Königstuhl). The comet was followed at Yerkes by Professor G. van Biesbroeck till June; like Schwassmann-Wachmann (1) it proved to be a short-period comet (6·4 years); as perihelion was not for two months after discovery, there was a slight increase of brightness, and the comet was visible with moderate telescopes. An interesting point about it is the prolonged approach to Jupiter that it made at its last aphelion passage; the distance was less than half a unit from July 1925 to October 1926, the minimum being 0·3 unit in March 1926; the perturbations must have been large; it will be of interest to calculate them, in view of the near agreement of inclination and longitude of perihelion with those of Denning's comet, 1894 I. The eccentricity is, however, much smaller, so identity does not seem to be very probable.

There is an interesting resemblance between the orbit of this comet and that of planet 525 Adelaide, discovered in 1904 and not seen since that year; their nodes and inclinations are practically identical, their eccentricities nearly so; the periods are 6·40 years for the comet and 6·10 years for the planet; but the fact that their major axes are inclined to each other by 76° seems to make identity quite impossible. The difference of aspect is a further argument against it; Dr. Palisa observed

Ref. No.	log q.	Period in Years or Eccentricity e in Hyperbolic Orbits.	Equinox.	Computer.	Reference.
153	9·872593	27·731	1818·0	A. C. D. Crommelin	*M.N.*, **90**, 322.
316	9·873276	28·0664	1873·0	,,	*M.N.*, **90**, 322.
424	0·162777	6·64628	1896·0	F. R. Cripps	*B.A.A.J.*, **39**, 261.
486	0·140436	6·48114	1910·0	,,	*MS.*
506	0·184334	17·79327	1913·0	F. E. Seagrave	*B.A.A.J.*, **40**, 86.
579	0·016711	6·01087	1927·0	M. S. de Mello e Simas	*A.N.*, 5635.
579	0·016656	5·98682	1927·0	F. E. Seagrave	*B.A.A.J.*, **39**, 333.
584	9·872120	27·90058	1928·0	A. C. D. Crommelin	*M.N.*, **90**, 233.
585	0·320163	6·40323	1929·0	C. H. Smiley	*B.A.A.J.*, **40**, 61.
586	0·183169	6·34422	1929·0	A. C. D. Crommelin	*B.A.A.J.*, **40**, 61.
587	0·309739	10·9011	1929·0	E. C. Bower, H. C. Willis	*L.O.B.*, 417.
..	0·138289	6·43405	1929·0	F. R. Cripps	*B.A.A.J.*, **39**, 261.
..	9·827489	..	1930·0	C. H. Smiley	*I.A.U. Circ.*, 246.

Adelaide visually with the great Vienna refractor, and made no note of anything abnormal in its appearance; but 1929 *a* was obviously a comet, and had a tail 2′ in length.

1929 *b* was discovered by Professor G. Neujmin at Simeis on August 2 in the course of the photographic observation of minor planets; its magnitude was 13·5, but in spite of its faintness it was well observed, and proved to be periodic, its period being 10·9 years, about 2 months shorter than that of Gale's comet 1927 VI. It is the fourth comet discovered by Neujmin, and the third periodic one.

1929 *c* was found on August 1 by Mr. A. F. I. Forbes of Rosebank, Cape Town, being his second cometary discovery; its magnitude was 11·0. As its south declination was 30°, and a mistake of 13° was made in the right ascension telegraphed to Copenhagen, observations were for some weeks confined to the Cape and Johannesburg, but it was subsequently observed at Helwan and Yerkes, Professor G. van Biesbroeck following it till the end of November, when its magnitude had sunk to 16·5. This comet likewise proved to be periodic, its period being 6·34 years.

The fourth discovery of the year was made by Dr. Wilk at Cracow Observatory on December 20; it is his second discovery, as he was one of the finders of 1925 XI. The comet was of the seventh magnitude, and as it was found a month before perihelion it remained an easy object up to mid-January; its orbit appears to be appreciably parabolic, with retrograde motion and high inclination; it makes a near approach to the orbit of Venus after perihelion in heliocentric longitude 356°, the distance being somewhat over a million miles.

A photograph taken at Engelhardt on December 28 showed two tails, 42′ and 12′ in length, the angle between them being 45° (*B.Z.*, 1930, No. 1).

On December 22 Dr. W. Baade photographed a tail over a degree in length.

Mr. E. F. Carpenter detected images of two objects, apparently comets, on plates exposed at Tucson, Arizona, on 1928 June 17 and 1929 November 2 (*P.A.S.P.*, 1929 October, and Harvard Card No. 100). No further observations were obtained in either case.

Fruitless search was made for three periodic comets during 1929; these were Perrine's comet of 1896 and 1909, Giacobini's comet 1896 V., and Metcalf's comet 1906 VI. Mr. F. R. Cripps's elements for the first of these were given in the last Annual Report. The present Report contains his redetermination of the orbit of 1896 V.; the best two previous determinations of the orbit gave periods differing by six weeks; the new value is near that of M. Ebell. Mr. Cripps carried the computation of the perturbations from 1896 to 1929, but his efforts were unavailing. Dr. G. Merton had re-examined the orbit of Metcalf's comet (*M.N.*, **82**, 382), but as it was observed for only two months in 1906 its present position is necessarily uncertain. As Perrine's comet was also missed at the more favourable return of 1922, it has probably undergone disintegration, like those of Biela, Brorsen, and Tempel (1).

A.N. 5673 contains a summary of the further researches of Professor M. Kamensky on the orbit and perturbations of Wolf's first periodic comet. In view of the fact that some very small discordances remained between his predicted orbit for the apparition of 1925 and the observed orbit, he has recomputed all the perturbations by the planets, from 1884 to 1925, with greater rigour than before, and is also recomputing the orbit at each apparition from the observations, in the hope of removing these small discordances. Most people considered the previous accord between prediction and observation in 1925 surprisingly good, considering the enormous perturbations which the comet underwent between 1918 and 1925; these changed the period from 6·79 to 8·20 years, and the perihelion distance from 1·582 to 2·347.

Several papers have been published dealing with orbit computation. In *A.N.* 5614 G. Bazenow gives a graph for obtaining the approximate geocentric distance of an object. B. Strömgren gives graphs for the same purpose in a paper on a modification of Olbers's method for parabolic orbits (*Publications of Copenhagen Observatory*, No. 66). In *A.N.* 5617 C. E. Adams gives a table for solving Euler's equation in parabolic orbits. In *A.N.* 5631 A. Wilkens discusses the solution of the fundamental equations in parabolic orbits, where five elements are given, *i.e.* two complete observations, and a third in one element only. In *A.N.* 5665 F. Gondolatsch discusses the motion in space of the material expelled in the tails of comets, with special reference to the case of Halley's comet.

Mem. R.A.S., **65**, Part I., contains tables for facilitating the computation of the perturbations of periodic comets.

L.O.B., No. 408, contains an important paper by N. T. Bobrovnikoff on the disintegration of comets. He commences by quoting the law of brightness of comets, $I = I_0/\Delta^2 r^n$ where Δ, r are the distances from

earth and sun, and I_0 is a constant for the particular comet; the most probable value for n is 4, of which 2 arises from geometrical causes, and the other 2 from physical action of the sun on the comet, varying as the inverse square of the distance; $n=4$ is adopted in the paper, but it is shown that the adoption of $n=3$ or 5 would not greatly change the conclusions. A study is then made of the correlation between the logarithm of the period in years and the absolute magnitude of comets; a graph shows that the relation is linear in the mean, though with considerable scattering; the formula is deduced, $H_0 = 9^{m}\cdot 8 - \log$ period (H_0 being the absolute magnitude of the comet); there is some evidence that the short-period comets are divided into a brighter and a fainter group, the latter having presumably followed their present orbits for a longer time. Also the comets that have very small perihelion distances deviate from the formula. It is conjectured that in these cases the sun causes evaporation of the nuclei.

The conclusion is drawn that comets are continually getting fainter owing to the loss of matter, which takes place chiefly in the neighbourhood of the sun, so that long-period comets keep their brightness longer. It is concluded that the comets cannot have been in the solar system for anything like so long a period as the planets; it is conjectured that they were introduced *en bloc* about a million years ago, being captured while the sun was passing through a nebulous region. The author has evaded the difficult question as to how such matter acquired elliptical motion; it would seem that the motion would be hyperbolic unless some agency intervened.

But, apart from this suggestion, the paper contributes valuable material towards the solution of the problem of the origin of comets.

Two errata may be noted in the table of cometary periods given in the paper; the period of 1873 VII. is given as 6·2 years; it was actually 28 years; also 1866 I. was associated with the Leonids, and 1862 III. with the Perseids; the author has interchanged the names.

L'Astronomie for May 1929 contains an article by M. Baldet, in which he gives a useful table of the elements of all comets known to have periods less than 170 years; the table is brought up to date, and includes Pons-Forbes and Schwassmann-Wachmann (2); there are 32 comets that have been seen at more than one apparition; of these 22 belong to Jupiter's family, 1 to Saturn's, 2 to Uranus's, and 5 to Neptune's.

Further errata in Sequel to Galle's Cometenbahnen (*B.A.A. Memoirs*, **26**, Part 2):

No. 178, 1827 II. T should be June 7, not January 7.

No. 395, 1890 VI. ω should be 162°, not 62°.

No. 403, 1892 II. ω should be 129° 19′ 51″; the quantity printed is π, not ω.

The above were communicated by Dr. C. H. Smiley.

Errata in *M.N.R.A.S.*, **88**, 294:

For Ref. Nos. 468, 509 read 469, 514 respectively.

Erratum in *Ency. Brit.*, 14th ed., vol. vi., plate facing p. 104. The

bright comet 1911 V. (Brooks), of which a photograph is reproduced, is not identical with Brooks's short-period comet, but has a very long period. A. C. D. C.

Double Stars.

Measures and New Pairs.—As has been the case for several years, important measures of double stars have been made at Mount Hamilton and Johannesburg. In *L.O.B.*, 413, Dr. Aitken has published his measures of no less than 296 stars discovered by himself already showing relative motion. No stars have been included with a change of position angle less than 10° unless there has been a definite change in the separation. The difficulty of the measures can be judged from the fact that for 223 pairs the maximum separation measured is less than 0″·4 and for 100 it is less than 0″·25. These double stars must play an important part in the not distant future in adding to our knowledge of stellar masses, and they may be recommended for observation for parallax and radial velocity.

The results of double-star work at Johannesburg have been published in circulars of the Union Observatory, except that Dr. Van den Bos continues to give notices of his new discoveries in the *B.A.N.*, No. 180 of which publication contains his 9th list, B1406 to B1713, besides 75 wider and fainter pairs which are unnumbered. *U.C.*, 78, contains 1115 measures of 500 pairs by Van den Bos, and *U.C.*, 80, a further 1393 measures of 604 pairs. These measures refer to double stars not discovered by himself and form an important addition to observational material concerning southern double stars. The published work of Finsen at Johannesburg concerns 294 new pairs, 31 wider and fainter pairs, and 730 measures of 320 pairs previously known (*U.C.*, 77 and 80). In *U.C.*, 77, there are also published data for I 1585 to I 1613, discovered by Dr. Innes too late for insertion in the southern double star catalogue, and also measures of previously known double stars by Innes and C. N. Jackson.

In *Bulletin* No. 103 of the Pulkovo Observatory, G. Shajn gives the results of a study of 7 double stars observed with the 40-inch reflector at Simeis. These are the first measures we have of double stars photographed with a reflector. In order to compare the results with visual observations, some plates have been taken through a yellow filter. The differential effects of atmospheric dispersion (coefficient of tan z) in the sense of late type *minus* early type are :

	Spectrum	″
95 Herculis	Ao–Go	–·073
α Herculis	Mb–F8	–·092
24 Comæ	Ko–A3	–·068

Other double star measures are indicated in the following table :—

Author.	Reference.	No. of Stars.	Notes.
Armellini, G.	*A.N.*, **237**, 167	52	Misc.
,,	*Accad. Naz. dei Lincei* X., series 6	56	,,
Baize, P.	*Journ. des Obs.*, **12**, 103, 117	139	,,
Barton, S. G.	*A.J.*, **39**, 120	125	Many Jonckheere.
Ellison, M. A.	*M.N.*, **89**, 138	61	Scheiner.
Espin, T. E. and Milburn, W.	*M.N.*, **89**, 268	34	New, $24<5''$.
		40	New, $26<5''$.
Hoff, A. H.	*A.J.*, **39**, 122	57	Photographic.
Luplau-Janssen, C.	*A.N.*, **235**, 357	62	Mostly Σ.
Kuiper, G. P.	*B.A.N.*, 168	27	Photographic.

In addition to these there have been lists of double stars picked up on Astrographic plates (*A.N.*, **235**, 421 and 425, and *A.J.*, **39**, 93).

M. Maggini has measured χ Ophiuchi as a close double with an interferometer (*A.N.*, **235**, 135). There have been a few measures of double stars on parallax plates (*P.A.S.P.*, **41**, 114, 235 ; *A.J.*, **39**, 154).

Orbits.—Dr. Van den Bos has made an extensive study of the system ξ Ursæ Majoris in *Mem. Royal Danish Academy*, 8th series, vol. xii, No. 2, p. 295. After correction for the short period irregularity a new orbit of the long period system is derived. S. E. Lauritzen discusses an apparatus for the determination of the elements of double stars and applies it to three stars (*A.N.*, **237**, 209). The following table gives the principal elements of these and other orbit determinations :—

Star.	Authority.	Reference.	P. Years.	a. $''$	e.
ξ UMa	Van den Bos	As above	1·832	0·051	0·531
			59·86	2·536	0·413
γ Centauri	,,	*U.C.*, 79	80·4	0·917	0·86
OΣ 79	Lauritzen, S. E.	*A.N.*, **237**, 209	92·0	0·54	0·605
OΣ 82	,,	,,	112·5	0·88	0·34
OΣ 489	,,	,,	14·8	0·88	0·60
η Coronæ	Silvernagel	*A.N.*, **234**, 441	41·62	0·907	0·276
OΣ 20	Luplau-Janssen, C.	*A.N.*, **236**, 93	163·4	0·57	0·30
,,	Zagar, Fr.	*Padova Obs.*, No. 7	139·1	0·77	0·63
99 Her.	Makemson, M. W.	*L.O.B.*, 409	56·0	1·03	0·787

R. Tschilschke has discussed the system of 70 Ophiuchi and retains the idea of disturbance by a third body (*A.N.*, **236**, 409). The large eccentricity of the orbit of γ Centauri has been verified by recent observations of the close approach. It is suggested that radial velocity

observations be undertaken. In *M.N.*, **89,** 548, C. Luplau-Janssen has given provisional elements for Σ 3001 from a very short arc (depending largely on measures of distance) and deduced the very large eccentricity of 0·95. In *A.N.*, **236,** 195, he gives ephemerides for 5 double stars.

Miscellaneous.—The long expected series of hypothetical parallaxes by Professor H. N. Russell has been published by him in collaboration with Miss C. E. Moor in *A.J.*, **39,** 165. Results are given for 1777 double stars. Eddington's mass-luminosity law has been used to supply the necessary equation to determine both the mass and the parallax instead of merely the parallax by the assumption of the mass. It is estimated that the probable error for those stars with orbits is 5 per cent., and for those depending only on arcs, 25 per cent.—apart from the errors of the double star observations. The errors for arcs only are comparable with the errors of spectroscopic parallaxes and smaller than those for trigonometric parallaxes less than 0″·03.

Observations concerning double stars which are urgently required are those to determine the distribution of mass between the components, and radial velocities. For the former it may be hoped that photographs for parallax may supply some data, while for the latter it may be hoped that the attention of observers may soon be attracted to this work. It is very interesting to note that progress has been made at Yerkes Observatory. In *A.J.*, **68,** 319 and **70,** 182, Y. C. Chang has given the results for 4 stars for which spectroscopic and visual orbits are now available—ζ Her., β Del., ξ Sco., η CrB.—and in *Ap.J.*, **70,** 256, *p* gives similar results for μ Orionis. The parallax can be at once derived and the sign of the inclination of the visual orbit determined. Chang has discussed the orientation of the orbital planes of 16 binaries for which the planes are definitely determined and found the distribution random (*A.J.*, **40,** 11). This investigation seems more satisfactory than the many based on larger numbers of binaries, for which the sign of the inclination is not known (Kreiken, *B.A.N.*, 169).

G. Shajn has discussed the mass-ratio of binary stars in *A.N.*, **237,** 57. He found that the mass-ratio approached unity with advancing type along both the giant and main sequence series of stars, but the ratio is too small for B type stars for these to form a connecting link between the giants and the main sequence stars. The following gives the mass-ratios for a few types :—

M giants . .	0·1
F giants . .	0·57
B2–B3 . . .	0·46
K2–M . . .	0·8

An increase in the mass-ratio is associated with a decrease in the difference of bolometric magnitudes. In *A.J.*, **39,** 57, J. H. Pitman has determined the masses and absolute magnitudes of 104 binary stars using trigonometric, spectroscopic, and Brill's hypothetical parallaxes (*Publ. Berlin-Babelsberg*, vol. vii., part 1). Results are also given for eclipsing variables. E. A. Kreiken in a number of papers has made

statistical discussions of double stars (*B.A.N.*, 173, 178, and *M.N.*, **89**, 647). The discussions cover spectral type, galactic latitude, separation, magnitude, and difference of magnitude. It is found that double stars are mainly dwarfs, that the B double stars are more concentrated towards the galaxy than ordinary stars, while the opposite is the case for K stars. There is no decided galactic concentration of double stars, and there is a large proportion of doubles amongst faint stars.

The hypothetical parallaxes of 5 double stars are given by Luplau-Janssen, *A.N.*, **235**, 401.

A critical review of the views of astronomers regarding the limits of separation of stars which should be observed as double stars is given by the late R. H. Curtiss in the *Journal R.A.S., Canada*, **23**, 423. The relative numbers of physical and optical systems are considered.

J. J.

Variable Stars.

The tendency of recent work on variable stars has been towards reclassification. This is exemplified on one hand by subdivisions of existing classes into more restricted types, and on the other by the detection of continuity between classes formerly regarded as essentially dissimilar. Researches in the latter direction have led to the discussion of "transition" types hitherto comparatively neglected. Of the several groups in Pickering's well-known classification, only novæ and eclipsing binaries remain unquestioned as isolated classes. In the unsettled state in which the subject now stands it seems best to group together all investigations either openly or tacitly concerned with the comparison or analysis of different types, and to retain the old headings for work in which no doubt of their validity is implied.

Classification of Variables.—The most comprehensive suggestion for a reclassification comes from Ludendorff (*Handbuch der Astrophysik*, **6**). who proposes the following groups :—

1. Novæ.
2. Variables resembling novæ, *e.g.* η Carinæ.
3. R Coronæ Borealis type, with protracted constant maximum.
4. U Geminorum type, with protracted constant minimum.
5. Long-period variables.
6. μ Cephei type—irregular variation through small range.
7. RV Tauri type, see p. 434.
8. Long-period Cepheids, with periods between 1 and 45 days.
9. Short-period Cepheids, with periods less than 1 day.
10. Eclipsing binaries.

In a later lengthy discussion of the two groups of Cepheids (*Sitzung. Preuss. Akad. Wiss., Berlin*, **5**, 3) he suggests the further division of the long-period Cepheids into two classes, with periods respectively less and greater than about 10·75 days, of which the stars in the latter class ("W Cygni" stars) have considerable affinity with long-period

variables. The possibility of this distinction was first indicated by a reconsideration of the significance of the relation, $e \cos \omega = a + bf$ (e = eccentricity; ω = angular distance of nodal point from periastron; $f = \frac{m_2{}^3 \sin^3 i}{(m_1 + m_2)^2}$; a, b = constants), obtained by considering Cepheids as double stars. Some time ago he pointed out that in this equation the constant a was different for the unsymmetrical (δ Cephei) and symmetrical (ζ Geminorum) types of light-curve, but that b was approximately the same for both. The violation of this rule by W Cygni and l Carinæ (periods > 10·75 days) led him to withdraw the relation in the *Handbuch der Astrophysik*, but he now reintroduces it by tentatively putting the exceptional stars in another class—the " W Cygni " class. Further justification for this treatment (the validity of which is nevertheless not regarded as established) is found in the following considerations: (1) The curve of frequency of Cepheids for different periods shows an irregularity on the descending branch (periods about 9–18 days). (2) The range of periods of the long-period Cepheids is much greater in proportion to the mean period than that of the short-period Cepheids or long-period variables. (3) Hertzsprung's relation between period and form of light-curve of Cepheids (see 1927 Council Note, p. 326) suggests the heterogeneity of these stars. Ludendorff repeats Hertzsprung's investigation with all the data now available, dividing the stars, for a first investigation, into two groups: (*a*) with periods greater than 9 days; (*b*) with periods less than 9 days. He confirms Hertzsprung's conclusions, and finds that stars of group (*a*) resemble Mira stars in the following points: (i) They show a secondary wave on the ascending branch. In Cepheids, however, this is restricted to stars with periods between 14 and 19 days, whereas it is found with Mira stars of all periods, though most frequently with the longer ones. (ii) They show an increase of $\epsilon = \frac{M - m}{P}$ (where $M - m$ is the interval of time between a minimum and the following maximum) and decrease of amplitude of light variation with decrease of period (*cf.* Araki's discussion, 1929 Council Note, p. 369). (iii) Other relations between form of light-curve and period. It is therefore considered that the possibility of a common origin for stars of group (*a*) and Mira variables, which has been obscured in previous discussions in which all Cepheids, instead of only those of longer period, have been grouped together, is strengthened. Stars of group (*b*), on the other hand, show no relation between period and ϵ or amplitude of light variation. The secondary wave in their light curves, if present, is on the descending branch, and its position there depends on the period with surprising regularity according to the formula, $\Delta = -0{\cdot}093P + 1{\cdot}00$, where Δ is the time between the secondary maximum and the preceding main minimum, expressed as a fraction of the period, and P is the period in days. This equation gives 10·75 days for the period at which the secondary and mean maxima coincide, and this is the mean value of the period of all known long-period Cepheids. It thus appears that the division into the two types of stars would have been better made at this period instead

of 9 days, and this is supported by the data. (*Cf.* Schilt's division described in last year's Note, p. 377, on which Ludendorff comments at the end of his paper.) Finally, the short-period Cepheids (periods < 1 day) are considered in the same way. As with the long-period Cepheids with periods less than 9 days, no relation appears between period and ϵ or amplitude of light variation. Secondary waves on the ascending branch do not appear, but they are frequent on the descending branch, especially with stars of relatively long period, where often two such waves appear. One of these follows a Δ, P relation, viz. $\Delta = -1{\cdot}07P + 1{\cdot}00$, giving P = 0·935 days for $\Delta = 0$ (the most frequent period for these stars is 0·810 days); the other gives an approximately constant value of Δ, viz. − 0·72. These short-period stars are remarkably similar to the long-period Cepheids with periods less than 9 days, except for the double secondary wave in the former, and the fact that a constant phase at minimum is frequent with them but rare with the longer period stars.

Another system of classification is adumbrated by B. P. Gerasimovič in *Harv. Circ.*, 342, arising out of the common period-spectrum relation which Shapley has shown to hold for cluster-type variables, Cepheids, RV Tauri stars, and long-period variables. This relation indicates that these types of stars form a homogeneous group, which Gerasimovič calls the "principal sequence." (Elsewhere—*Harv. Bull.*, 864—he remarks that the principal sequence contains semi-regular variables other than those of the RV Tauri type, of which AI Scorpii seems to be an example.) The variation appears to be controlled by one governing factor—the mean density. Other variables exist which do not show this period-spectrum relation, and the beginning of an attempt to classify them is made by considering stars whose periods (of "intermediate" type) fall between 40 and 100 days. Stars with these periods (which are probably more numerous than is at present realised, as their chances of discovery are small owing to their small range of light variation), other than those of the principal sequence, are divided into three main groups: (*a*) Periodic variables (Z Leonis group); (*b*) μ Cephei stars; and (*c*) cyclic variables. The periodic variables show well-defined periods subject only to minor irregularities, viz. erratic irregularities and systematic changes of period of harmonic or linear character. Their light changes are small, and their spectra are mainly of M type without emission lines. The μ Cephei stars have long periods and variable ranges of variation. Their periods (of several hundred days) take them out of the "intermediate" group, but their properties are not irrelevant, for two variables of the Z Leonis group show superposed μ Cephei characteristics. A variation of shorter period is suspected for μ Cephei also, so that there is a possibility that other μ Cephei variables also show the Z Leonis type of variation. The cyclic variables are those which exhibit such changes of period as to make the conception of a period rather misleading. Their light changes can be represented better by "cycles" (see definition in last year's Council Note, p. 383). "We shall call cyclic variables all semi-regular variables that have no regular period. Cyclic variables are divided into

two groups : erratically cyclic variables, and regularly cyclic variables." From the study of six erratically cyclic variables (viz. TZ Aql, UX Aur, V Lyn, TX Dra, TV And, UZ Aur) it appears that (1) the frequency curves of cycles are approximately symmetrical and show well-defined maxima corresponding to the most frequent cycle ; (2) cycles are confined within relatively narrow limits ; (3) the mean cycles are between 66 and 92 days. These stars may be connected with variables of the Z Leonis type by means of two or three periodic variables like UU Herculis or SW Persei and R Lyræ.

The investigation of semi-regular variables, which fall within the range of period just referred to, is continued by B. P. Gerasimovič in *Harv. Circ.*, 338, by the study of V UMi and SW Per. The former star has an M4-type spectrum and a period of about 72 days, and it therefore departs from the period-spectrum curve connecting Cepheids with long-period variables. It is pointed out that no trace of RV Tauri variation is shown by the material under discussion. SW Per also cannot be of RV Tauri type. The most important feature of its variation is a peculiar change of period which makes the conception of " cycles " preferable to that of periods for its discussion.

R Sagittæ, a typical RV Tauri star, which has been more or less continuously observed for the last 70 years, is discussed by B. P. Gerasimovič and L. Hufnagel in *Harv. Circ.*, 340. The data suggest that the changes of period (P) might be accounted for by the existence of a simple or fundamental period corresponding to an ordinary Cepheid curve, which is perturbed by a superposed wave of twice the period. This hypothesis is strongly confirmed by spectroscopic data, and is regarded as one of the best established results of variable star astronomy. It is suggested that the changes in period signify sudden expansions or contractions of the star owing to some internal cause. The changes in mean density (ρ) obtained from the formula, $P^2\rho$ = constant, are not greater than 2 per cent.

A more general discussion of the characteristics of RV Tauri stars is given by B. P. Gerasimovič in *Harv. Circ.*, 341. Only 12 such stars are certainly known, although it is possible that some long-period variables may fall within the class. The 12 stars are RV Tau, SS Gem, U Mon, TT Oph, TX Oph, UZ Oph, AC Her, R Sct, AR Sgr, DF Cyg, R Sge, V Vul. The characteristics of these stars are as follows : " They vary continuously in brightness, their minima being alternately shallow and deep ; the difference in brightness between successive minima is variable, so that in the course of a few years the shallow and deep minima may interchange. The light-curve varies, sometimes resembling that of β Lyræ, sometimes that of δ Cephei. Maximum light is slightly variable, and other irregularities often complicate the light variation considerably." The " period " may be regarded as either of two intervals, viz. the interval between two successive minima (the " fundamental " period) or the interval between two successive minima of the same kind (the " formal " period). The latter, which usually exceeds 50 days, is twice the former. The stars, like regular Cepheids, show a pronounced galactic concentration, and are remarkably clustered

between 350° and 36° of galactic longitude. The spectra are variable and have a pronounced c-characteristic, so that the stars are probably very luminous. They show the same period-spectrum relation as Cepheids when the "fundamental" period is used. The radial velocities are variable, with ranges from 25 to 50 km./sec.—the same order of magnitude as that shown by regular Cepheids. Some of the stars show variations in the velocity of the centre of gravity, but for these the data for various years do not yield a mean velocity curve. Observations in one year, reduced by means of the "fundamental" period, show a large scattering, so that a velocity curve cannot be derived, though in some cases this period represents the observations fairly well. The double, "formal," period gives fairly good mean curves, which are strikingly correlated with the light-curves for the same period. The velocity curves are mirror images of the light-curves with some displacement of phase, as with regular Cepheids but larger. The alternation of shallow and deep minima shows a varying amount of irregularity, which appears to be greater for the stars with longer periods. Changes of period—in some stars cyclic, in others discontinuous—have been observed, and also jumps in phase. Erratic irregularities in the times of minima are very marked and troublesome for some of the stars. A relation between RV Tauri stars and Cepheids is suggested by the following facts: (1) Both types show super-giant spectra and strong galactic concentration. (2) They show the same period-spectrum relation. (3) The changes of spectra and the behaviour of the photographic and visual light-ranges in the two groups indicate similar changes in temperature. (4) The mean ranges are the same for the two groups. (5) They show similar variation in radial velocity and correlation of radial velocity with light-curves.

In attempting to explain these phenomena, the author shows first that the superposition of two waves, of periods P and 2P respectively, of which the latter is sometimes perturbed by some unknown physical factor in addition to persistent irregularities of smaller range, can be made to represent the characteristics of some of the stars. The fundamental P-wave is regarded as a typical Cepheid variation, and the superposed irregularities, including the 2P-wave, are called the "RV Tauri anomaly." No continuous transition between ordinary Cepheid and RV Tauri stars can be detected, and it is tentatively concluded that the RV Tauri anomaly represents an isolated phenomenon. It is probably a manifestation of an unstable configuration, and passes as soon as the instability ceases.

An attempt to form a working hypothesis of its origin is then made. The pulsation hypothesis of the regular Cepheid variation, of period P, is assumed, but no form of pulsation hypothesis can explain a wave of longer period than P. A forced oscillation must therefore be looked for, which, since it is so nearly equal to 2P in period, cannot be independent of the Cepheid variation. External causes are regarded as improbable, and the suggestion is made that the cause may be found in a periodic perturbation of the outer layers of the star arising from relative displacement between them and the much more massive core which, as indicated by Jeans, is far less easily disturbed and determines

the course of evolution of the star. This explanation, however, is not stressed, and is regarded as probably too simple to account for the extremely complicated phenomena.

In view of Gerasimovič's remark that the RV Tauri anomaly appears to represent an isolated phenomenon, it is interesting to note that E. Leiner (*A.N.*, 5675), in giving particulars of VY Cassiopeiæ, an M5 star with period about 99 days, remarks that it appears to be an RV Tauri star or a link between RV Tauri and Mira stars. (See also Beyer's remark on TX Aquilæ in the next paragraph.)

An independent discussion of the variables with periods between 30 and 100 days is given by M. Beyer in *A.N.*, 5616. He has been engaged since 1922 in a study of all such variables accessible to him, and the investigation has reached a stage at which a report can usefully be made. This range of periods contains only a small fraction of the known variables, and among them the RV Tauri stars are conspicuous, though there are a few long-period and Cepheid variables also, so that length of period and amplitude of light variation afford no certain limits for denoting the character of a variable. The ultimate object of the work is a classification, as exact as possible, of the variables in different groups. The observations so far obtained show that a sharp classification is possible only for a few of the stars. The great majority show irregularities, especially in the amplitude of light variation, but also, within certain limits, in the length of period. Sudden periodic changes and phase displacements occur with unusual frequency in these stars. Sometimes even a sudden or gradual change of the whole character of the variation takes place, from δ Cephei to RV Tauri type or *vice versa*, or the light may remain constant for some time. Specially complicated are the cases (*e.g.* UU Herculis—see last year's Note, pp. 332–3) in which two quite different periods exist, of which from time to time one gives place to the other. Probably, however, all these phenomena represent transition stages between normal types, but their investigation is not less important than that of the normal types. A detailed discussion of SS Geminorum and TX Aquilæ is given. The former star is of RV Tauri type, although for some time in 1923–24 the light-curve, without marked difference of period, was approximately of δ Cephei type. The period, however, as well as the range of variation, always shows small irregularities. TX Aquilæ appears to represent a stage between RV Tauri and δ Cephei conditions.

D. B. McLaughlin (*Astron. Journ.*, 932) approaches the question of classification by considering the relation to period of the interval, time of velocity minimum (negative maximum) *minus* time of light maximum, for those intrinsic variables which show oscillating velocity changes. Of the 23 stars considered he finds that, with one exception, those with periods between 3 and 17 days (an interval which includes the majority of Cepheids) have a value for this interval (denoted by Δ) not greater than 0·1 of the period, P, while stars outside those limits, on either side, again with one exception, have Δ/P greater than 0·1. There are indications of a regular increase of Δ/P as the period departs from that corresponding to the maximum frequency of Cepheids. This supports

the deduction from other phenomena that all regular or semi-regular variables (except eclipsing and ellipsoidal variables) are different species of the same genus. The importance of obtaining simultaneous photometric and spectrographic observations of variables is emphasised, on account of the importance of the lag between the light and velocity curves thus revealed. (See Sanford's investigation of RU Cam, p. 440 of this note).

An investigation of R Lyræ by J. Mrazek (*A.N.*, 5658) has some bearing on this matter. R Lyræ, of spectral type M*b*, has been considered an irregular variable. Mrazek, however, finds, from observations scattered over many years, a fairly constant period of about 41·3 days, which characterises both the brightness and the radial velocity (see, however, 1927 Council note, p. 334). The relation between the brightness and velocity curves, and the character of the curves themselves, are similar to those for Cepheids. The star, in fact, shows the general characteristics of Cepheids except that its absolute magnitude (− 0·6 trigonometric, − 1·4 spectroscopic) disagrees with Shapley's curve, which would give − 5·4 for a period of 41 days. M'Laughlin, in the paper just mentioned, points out that the relation of Δ/P to period for R Lyræ is consistent with that shown by the stars he has considered, and he remarks that R Lyræ appears to represent the complete bridging of the gap between Cepheids and Mira variables. Mrazek finds further that, in addition to the Cepheid type of variation, there is a variation of the radial velocity of the "centre of gravity" of this star with a period of 5 years, suggesting that R Lyræ is one component of a double star with this period of revolution.

Novæ.—In *Harv. Bull.*, 870, H. H. Swope reports the discovery, on a plate taken on 1929 June 20, of a nova in Scorpio, HV 4716. Its maximum photographic brightness was about 9·4 mag., on June 21.

Records of the photographic brightness of Nova XX (100, 1927) Tauri at intervals from its discovery on 1927 November 18 to 1928 August 28 are given by A. A. Wachmann in *A.N.*, 5613. In *A.N.*, 5640, M. Beyer gives observations and light-curves of the three novæ, DO Aquilæ, EL Aquilæ, and XX Tauri, and further observations of the last-named two stars are recorded by W. Luther in *A.N.*, 5644. Observations of Nova Pictoris during the period 1928 March 25 to 1929 February 18 are given by Fr. Pingsdorf in *A.N.*, 5646, and in *Astron. Iakt. och Under., Stockholm*, **11**, No. 4, p. 3, A. Jenvall reports, with photographs, tables, and notes, on spectrographic observations of Nova Cygni No. 3 on several dates in 1920 August and September.

A general consideration of the physical changes which must occur in a star in order to account for its appearance as a nova is undertaken by S. R. Pike in *M.N.*, **89**, 538. Assuming that no other star is concerned in the phenomena, the change in magnitude must be due to a change in surface temperature or surface area or both. By considering how the brightening is related to these factors the author shows that for Nova Aquilæ, 1918—the only star for which all the necessary data are available—the observed changes cannot be accounted for by an

increase of surface temperature alone unless such an increase is fantastically high. If the temperature at maximum was between 25,000° and 60,000°, the radius must have increased 50- to 90-fold. From the time occupied by the rise in brightness the velocity of expansion of the photosphere is determined to be of the order of 200 km./sec. This is not necessarily the velocity of the outflowing gases, because the depth of the photosphere may have changed with the expansion, and it is shown that, if so, the actual velocity of the stellar material must have been greater than this—possibly much greater. The history of the star after maximum is investigated by a determination of temperatures from the degree of ionisation indicated by the *H*, *He*, and nebulium lines in the successive spectra. The conclusion is reached that either the star returns to its previous magnitude at a higher temperature and smaller radius than it had originally, or the temperature never rose at any stage by more than 1000° or so above normal. Milne's theory of the expulsion of atoms under radiation-pressure, coupled with the observed velocities, would require a small rise of temperature. The data point to the presence of a great abundance of hydrogen in the atmosphere of the star.

The theories of Gehne and Barabascheff concerning the origin of novæ have been further developed. Gehne, who assumes that a nova is a white dwarf returning to a normal density on account of failure of the internal energy supply, points out (*A.N.*, 5619) that two factors would be involved in the outburst—(1) a pure expansion, and (2) a shooting-up of hot material, like huge prominences, from the deeper layers. The sudden accession of brightness would then be due partly to increased surface area and partly to increased surface temperature. Taking Sirius B as a typical white dwarf, and 100,000-fold (12·5 mag.) as a representative increase of brightness in a nova outburst, it follows that the brightening can be divided between these two causes so as to increase the effective temperature from 8000° to 25,000°, and the radius from 22,000 to 700,000 km., and to decrease the mean density from 60,000 to 2. The velocity of expansion observed in Nova Geminorum (1912) would allow of this change taking place in a minimum time of twenty minutes. The layers from which the hot material must rise to give this augmentation of surface temperature must, for theoretical reasons, be very near the surface. The question of energy supply is next considered. The energy required for the outburst is estimated by calculating how much energy would be liberated in the contraction of the radius of Sirius B from 700,000 to 22,000 km. This is found to be $4{\cdot}5 \times 10^{49}$ ergs., or $2{\cdot}8 \times 10^{16}$ ergs. per gm. From R. H. Fowler's consideration of the properties of dense matter, it is calculated that this energy would be available if the density of the material were 600,000, and from the theoretical distribution of matter in the star it is found that the innermost 94 per cent. of the mass has this mean density. Hence, if Sirius B were suddenly to return to a normal density it would have almost, but not quite, sufficient energy to expand to a radius of 700,000 km.

Barabascheff postulates that novæ are single stars which have under-

gone an explosion and a subsequent pulsation. He has previously shown how to calculate the changes of radius, mean density, parallax, etc., of the star on this hypothesis, and he now (*A.N.*, 5634) compares the theoretical values with those observed by Hubble and Duncan for the angular diameter of the nebulous star, Nova Aquilæ No. 3, at various times after the outburst. He finds a good agreement. A comparison of the theoretical growth of linear diameter with that calculated on the assumption that the radial velocity observed is the velocity of expansion of the star, also shows a good agreement. The assumption is then made that the fall of brightness of the nova is due to absorption of the star-light by the surrounding nebula. After giving reasons for believing that the nebula is not an empty shell but occupies the whole space between its outer boundary and the star, the absorption coefficient is calculated which would be necessary to bring about the observed fall of brightness. The results are considered sufficiently reasonable to make the assumption very probable.

β-Lyræ Type and Eclipsing Variables.—Visual photometric observations of eclipsing variables are given by D. B. M'Laughlin in *Astron. Journ.*, 920, and photographic observations of 16 such stars, obtained with the 30-inch Thaw refractor by F. C. Jordan, are recorded in *Pub. Allegheny Obs.*, vii., No. 2.

A period-spectral type relation of the form, spectrum = A3 − 34 log P, where the intervals between spectral classes (*e.g.* A3 to A4) are represented by 0·1, is suggested for variables of the W UMa type by B. Kukarkin in *Ver. v. Freund. d. Phys. u. Ast. in Nishni-Novgorod*, I., No. 7. The photographic light-curve of VW Cephei—probably the most accurate yet obtained for a star of W UMa type—is given by H. van Gent in *B.A.N.*, 175.

In *A.N.*, 5620, S. Tscherny, in continuation of his study of β Lyræ, shows that the orbit is a " periplegmatische " curve, *i.e.* a curve which lies between two concentric circles, is tangential to one or the other of them at each maximum or minimum of the radius vector, and is such that the tangent to the inner circle at the point at which it intersects the radius vector, always faces the concave side of the curve. The orbit has the following properties: (1) It is not closed and has an infinite number of points of intersection which lie on concentric circles (" iso-pyknoten "). (2) The points of intersection are more crowded near the boundaries than in the middle of the ring-shaped region within which the curve lies. (3) Two different tangents can be drawn through each point of intersection.

Algol as a three-body system is discussed in *A.N.*, 5653, by M. la Rosa, who claims that the phenomena are explained remarkably well by his ballistic theory of light-propagation and provide a new and striking proof of the theory.

Cepheids.—A preliminary detailed account of the plan for co-operative photometric observation of Cepheids is given by J. Mascart in *Lyons Obs. Bull.*, xi., 91.

As the first step in a large programme of determinations of the accurate light-curves of Cepheids from Harvard plates taken during this century, L. V. Robinson (*Harv. Bull.*, 871) gives elements of variation for 11 such stars and photographic light-curves for 10 of them.

In *Arch. des Sciences*, **10**, G. Tiercy applies his method of analysing Cepheid variation by means of the properties of the parameter q (see 1929 Council note, p. 373) to S Sagittæ and X Sagittarii, and in **11**, 15, to W Sagittarii. In the same journal, **10**, 363, and more thoroughly in *Osserv. e Mem. del R. Osserv. Astrof. di Arcetri*, **45**, 11, he pursues more general aspects of the investigation—in the latter paper in the light of data for SU Cas., T Vul., W Sgr., X Sge., and S Sge., and less complete data for Y Oph. and X Cyg. Curves are given expressing mean radiation and mean absolute visual magnitude in terms of mean colour-index, and mean colour-index in terms of period. For spectral type F5, the actual colour-index, total radiation, and visual absolute magnitude are expressed in terms of colour-index.

The investigation of η Aquilæ begun by F. Henroteau has been continued with the collaboration of A. V. Douglas (*Pub. Dom. Obs. Ottawa*, **9**, No. 7). The radial velocity curve for 1927 shows a decrease of amplitude from about 44 to 36 km./sec. as compared with 1924 and 1925, and there is a decrease in maximum radial velocity of about 12 km./sec. This is similar to results found for other Cepheids. The variations of intensity of several spectrum lines have been measured microphotometrically and are shown in tables and curves.

W. Zessewitsch (*Lyon Obs. Bull.*, xi., 49A), in a study of the Cepheid SX Aquarii, finds an irregularity of period and also variations of brightness at corresponding points of different periods which may be either real or due to a property of the eye by which it estimates magnitudes differently in different circumstances.

In *Ap. J.*, **68**, 408, R. F. Sanford gives particulars of RU Camelopardalis, a Cepheid for which the light and velocity curves, though showing the same period, do not exhibit the usual correspondence for Cepheids. Minimum light is nearly coincident with the velocity change from approach to recession, and maximum light with the change from recession to approach, while maximum velocity corresponds approximately to median magnitude on the rising branch of the light-curve and minimum velocity to median magnitude on the falling branch. On the hypothesis of a symmetrical pulsation of a spherical star, maximum light synchronises with minimum diameter and minimum light with maximum diameter. These phenomena could be explained by assuming that the star is spheroidal with the axis of rotation pointed towards the earth, and that it oscillates without change of volume through varying degrees of oblateness. The spectrum varies during the period, showing three distinct stages—Roe, Ko, Ro.

On the basis of a discussion of RR Geminorum, N. Ivanov (*A.N.*, 5681) concludes that the periods of short-period Cepheids probably undergo periodic variations, and that the light-curves vary from epoch to epoch and are often complicated by secondary oscillations which are themselves probably periodic.

The relation between the colour-curves and periods of Cepheids is considered by B. Okunev in *A.N.*, 5660. After a discussion of difficulties arising from lack of homogeneity of data he directs attention to relations between these characteristics of the variation which are similar to those found by Hertzsprung to exist between period and form of light-curve (see 1927 Council Note, p. 326). For periods below about 6 days (cluster variables excluded) the colour-curve is similar to the light-curve, showing no secondary waves. A secondary wave appears on the descending branch above 7 days ; it is situated on the maximum for periods between 10 and 14 days and on the ascending branch for longer periods. It is stated that these phenomena cannot be explained by Eddington's pulsation theory or Jeans's fission theory in its present form.

An attempt is made by C. Luplau-Janssen (*A.N.*, 5636) to determine the zero-point of the period-luminosity curve for Cepheids by comparing the brightness of Cepheids and novæ. It is assumed that the absolute brightness of a nova at maximum, wherever it occurs, is a constant quantity which is evaluated at − 6·82 (the absolute magnitude throughout is defined as the magnitude at a distance of 1 parsec) from parallaxes based on the galactic concentration and distribution of novæ in our system compared with those of the B and O type stars. Hubble's data for the Cepheids in the Andromeda nebula give a photographic apparent magnitude at maximum of 18·6 (corresponding to 19·0 median magnitude) for a period of antilog. 1·43 days, while Lundmark's value for the maximum photographic apparent brightness of novæ in that nebula is 17·0 m. From this it follows that novæ at maximum are 2·0 mag. brighter than the median brightness of Cepheids of the period mentioned, so that the absolute value of the latter must be − 4·82 m. Shapley's curve, however, gives for Cepheids of this period an absolute brightness of − 7·97 m., so that a correction to the zero-point of Shapley's curve of + 3·15 m. appears to be necessary. The mean brightness of ordinary giant stars of the same spectral type (viz. G5) as the Cepheids considered is, according to Adams and Joy, −4·5—in good agreement with the value here suggested for the Cepheids.

Long-period and Irregular Variables.—The proper motions of the long-period variables, X And., S Cas., R Per., U Ser., S Cyg., Z Peg., are given by A. S. Young and A. H. Farnsworth in *Astron. Journ.*, 916.

Evidence of the presence of scandium oxide bands in the spectrum of Mira is given by F. E. Baxandall in *P.A.S.P.*, **41**, 168.

In *Harv. Bull.*, 869, B. P. Gerasimovič reports an investigation of SX Her., which has, among other peculiarities, the earliest known spectrum of all long-period variables (K2 at maximum).

The period of R Hydræ, which since 1780 has decreased from about 500 to 400 days, is shown by R. Müller (*A.N.*, 5668) to have reached a minimum value in 1918 and to be now increasing again. There is some evidence of a previous increase between 1662 and 1708, but the uncertainty of the observations prevents a definite conclusion on this point.

L. Campbell (*Harv. Bull.*, 864) reports that SS Aurigæ has recently undergone peculiarities similar to those shown by SS Cygni in 1907–09.

An account of UZ Persei, an M4 variable with the unusually long period of about 907 days and a range of less than 0·5 magnitude, is given by B. P. Gerasimovič in *Harv. Bull.*, 864. The only other two variables (except the eclipsing binary, ϵ Aurigæ) with periods exceeding 800 days (viz., S Persei and V Hydræ) show also short-period oscillations, and such a variation has been found in UZ Persei, of period 90 days. The other stars, however, have a far larger range of variation. It is suggested that UZ Persei might have some importance in connection with Huffer's suggestion that a large proportion of red giants are variable. TW Pegasi, reported on by the same writer in *Harv. Bull.*, 867, is a very similar star.

In *Nature*, **124**, 93, however, W. Zessewitsch, commenting on the resemblance of UZ Persei to μ Cephei, points out that he has found three oscillations in the latter star, with periods of 90 days, 600 days, and 13 years. Examining Gerasimovič's data for UZ Persei he finds evidence of a period of 14 years, and therefore regards the star as being of μ Cephei type.

Another variable of μ Cephei type—AC Cygni—is discussed by W. Zessewitsch in *A.N.*, 5625. It shows a regular variation, of period 118·3 days and brightness amplitude 0·25 mag., on which is superposed an irregular variation of maximum amplitude 1·5 mag. The possibility of a systematic classification of stars of this type is suggested, and it is surmised that the regular variations might be due to a rotation of the star on its axis in 236·6 days.

In *Pop. Ast.*, **37**, 270, D. B. M'Laughlin and R. M. Petrie report on a search for a relation between ΔM (difference between magnitude at minimum and at the time considered) and the intensity ratios, δ/γ and γ/β of the bright hydrogen lines, $H\delta$, $H\gamma$, $H\beta$, in long-period variables. They find such a relation only when the stars are separated into spectral classes. For types M5*e* and M3*e*, δ/γ and γ/β respectively decrease continuously with increasing ΔM, while in the latter class, δ/γ has a maximum value for $\Delta M = 5$. In M6*e* stars, δ/γ has a maximum value for $\Delta M = 4{\cdot}4$, and γ/β for $\Delta M = 5{\cdot}5$. Considered as functions of spectral class, both ratios show marked increase from M2 to M7. For spectra of class M4 and earlier, $\delta/\gamma < 1$, but for M5–M7 spectra, the ratio increases from about 1·5 to 4. There is a linear relation between the logs of the ratios δ/γ and γ/β. An explanation is suggested in terms of the oppositely directed effects of titanium oxide absorption and increase of excitation with light-range.

An investigation by H. H. Swope (*Harv. Bull.*, 867) of 57 long-period variables in Milky Way field 185 throws light on the results of two researches referred to in last year's Council note. The inclusion of faint stars shows that the most frequent period for long-period variables (given by L. Campbell and A. J. Cannon as about 300 days for stars with known spectra and 280 days for all the stars considered taken together) depends on the brightness of the stars, as Campbell and Cannon's results suggest. The most frequent general period found by

Miss Swope is 217 days. Further, the bi-modal distribution of the periods of long-period variables in this field, found by Shapley and suspected of unreality, is shown to be an illusion due partly to the inclusion of wrongly adopted periods and partly to the effects of selection.

In *A.N.*, 5645, F. Lause records observations of three interesting irregular variables, TW Pegasi, Z Eridani, and RR Eridani.

General.—The spectrum of WZ Draconis, a variable of undetermined character, is reported by A. Schwassmann and A. A. Wachmann (*A.N.*, 5613) to be of type G5*p* with bright hydrogen lines.

The variables in the neighbourhood of η Carinæ are used by D. B. M'Laughlin (*Astron. Journ.*, 917) to determine the distances of the star clouds in that region. 126 stars—viz. 60 eclipsing binaries, 46 Cepheids, and 20 long-period variables—are considered, occurring in an area about 8 degrees square centred on the nebula. No preference for particular magnitudes is shown. When the periods of the Cepheids are plotted against their apparent luminosities, points are obtained which are considered as lying along four directions parallel to the Harvard period-luminosity curve. The displacements from that curve are then used to estimate the parallaxes of the corresponding groups of Cepheids, which are of the order of 0″·0009, 0″·0004, 0″·0002, and 0″·00007. The long-period variables are divided into two groups with the point of division at mag. 11·0, and, assuming Merrill and Strömberg's value of + 0·1 for the absolute magnitudes, the resulting parallaxes indicate (1) a group of stars four times as near the Sun as the nearest group of Cepheids, and (2) a group between the nearest two groups of Cepheids. The division, however, is arbitrary, and the results are not regarded as of great weight.

The eclipsing variables show a normal distribution of periods. The upper limits of their densities are calculated, tabulated, and discussed. Assuming a value, − 0·6, previously derived for the average absolute magnitude of an eclipsing pair at maximum light (stars of specially short period excluded), the parallaxes of the stars are calculable. A minimum frequency at mag. 11·0 suggests a division at this point, and the two groups thus formed are found to have mean parallaxes of 0·00076 and 0·00018. The first figure suggests the nearest two strata of Cepheids, and the other the third stratum. Another estimate of parallaxes is obtained by plotting the density of the bright star of each eclipsing system which has been spectrographically observed in the sky in general against the absolute magnitude of the pair at maximum. With very few exceptions the points are found to occupy a narrow band on the diagram. A similar plot for the Carina stars, using upper limits of density and apparent instead of absolute magnitudes, gives a much wider band, and, by virtue of a result obtained from observations over a wide region of the sky, that the average upper limit of density of stars in general is approximately the same as the average density of the brighter component of an eclipsing binary, the displacements of the points from the former narrow band give a measure of the parallaxes

of the Carina stars. The stars are divided into four groups, of which the parallaxes come to 0″·0002, 0″·0003, 0″·0005, 0″·0014.

The general conclusion is that the star clouds of the η Carinæ region are of great depth and composed of at least four strata, each of which may be of small depth compared with its distance from the Sun. The farthest known variables in this region are at distances of about 15,000 parsecs. The distances obtained by means of the eclipsing variables are regarded as only supplementary to and confirmatory of those given by the Cepheids.

An independent account of the investigation is given in *Pop. Ast.*, **37**, 269.

A comprehensive and valuable series of nine papers by P. W. Merrill on variable stars, in which particular attention is given to long-period variables, is begun in *Pop. Ast.*, **32**, 60, and continued on pp. 253, 444.

H. D.

Solar Activity in 1929.

Sunspots.—Although it seems certain that the decline of solar activity has set in after the double-peaked maximum of 1926 and 1928, the year 1929—especially its latter part—ranks as a period of considerable sunspot activity. Groups of spots large enough to be naked-eye objects numbered not less than 18, 9 of which appeared during the last three months of the year. Of these groups, 6 had at some time of their history an area equal to or exceeding 1000 millionths of the sun's hemisphere, the corresponding number for 1928 being 11. The times of central meridian passage and latitudes of these largest spots seen during 1929 are as follows :—

(1) Jan. 17·4	7° N.	(4) Nov. 30·3	16° N.
(2) Mar. 11·0	9° S.	(5) Dec. 16·5	6° N.
(3) July 10·7	6° S.	(6) Dec. 27·5	16° N.

Group No. 1 underwent several changes in appearance. No. 2 was associated with a large metallic prominence (*Journ. B.A.A.*, **39**, 190). No. 3 had a very rapid growth, its area increasing from 40 millionths on July 9 to 1100 millionths on July 11. No. 5 was accompanied by smaller groups on the same meridian, ranging from latitude 20° N. to 13° S. No. 6 was a return or revival of No. 4, which was also the return of a large group (central meridian passage Nov. 3·7) marking a specially active region (*Observatory*, **52**, 365). The faculæ and bright hydrogen flocculi accompanying group No. 6 were very extensive, and the area was preceded by a long dark filament showing line-of-sight motions (*Nature*, **125**, 26). Nos. 2, 3, 4, and 5 were each within $3\frac{1}{2}$ days of the sun's central meridian at the times of commencement of magnetic storms (recorded ranges at Greenwich : in D $\geq$ 30′, or in H or V $\geq$ 150γ). A large unipolar spot, crossing the central meridian on July 17·1 in latitude 16° S., had an intense magnetic field of 4200 gauss (*P.A.S.P.*, **41**, 315). No significant magnetic disturbance was

registered at Abinger about July 17, but on August 14–15, *i.e.* about one synodic solar rotation later, a disturbance occurred with a range in H of over 200γ.

H. W. N.

The Prominences, 1929.—The mean daily areas in square minutes of arc derived from the Kodaikánal photographic records are as follows :—

	North.	South.	Total.
1929 January to June . . .	2·55	2·58	5·13
July to December . . .	2·07	3·03	5·10

The mean daily numbers were 15·2 and 14·2 for the first and second half-years respectively. Compared with the year 1928, areas and numbers show a decrease of 29 and 23 per cent. respectively.

The distribution of prominence areas shows that the maximum of activity during the year is between 20° and 30° of latitude in both the hemispheres. A peak which existed near 60° in the southern hemisphere during the first half-year is found to be 10° lower down during the second half-year. The activity near the poles has practically subsided.

An eruptive prominence photographed on 1929 September 5 reached a height of 13′, or nearly 567,000 km. above the chromosphere.

Prominences exhibiting metallic lines numbered 52 as against 79 in the year 1928. None of these was beyond latitude 32°·5. Displacements of the hydrogen line in the chromosphere and prominences observed during the year numbered 598 as against 1067 in the previous year. Of the displacements, 354 were towards the red, 214 towards the violet, and 30 both ways simultaneously. Bright reversals of the *Hα* line in the neighbourhood of sunspots numbered 813 as against 915 in 1928. Displacements of the *Hα* line on the disc totalled 172, a decrease of 51 per cent. on those of the previous year. Of these displacements, 124 were towards the red, 44 towards the violet, and 4 both ways simultaneously. D3 was observed as a dark line on 790 occasions, as against 841 during 1928.

The mean daily area of prominences projected on the disc as absorption markings in hydrogen light was 4259 millionths of the sun's visible disc, an increase of 4 per cent. on the year 1928. The distribution in latitude is closely similar to that of prominences on the limb.

A. L. N.

Solar Research in 1929.

Composition of the Sun's Atmosphere.—Russell gives (*Ap. J.*, **70**, 11) a very full account of our present knowledge of the chemical constitution of the reversing layer. He shows that the value of the excitation potential of the strong lines of an element in the observable region of the spectrum is the decisive factor in the presence or absence of an element in the list of elements present. Hydrogen is abnormally abundant, and in the case of other elements the more excited atoms,

though falling off in abundance compared with the less excited ones, are in excess of the proportion indicated by theory. (Eddington makes an alternative suggestion that they are too few and that the corresponding spectral lines are disproportionately strong because of a shortage of the excited atoms in the higher solar levels capable of weakening the absorption lines by emission.) Unsöld (*Ap. J.*, **69**, 322) checks the views of Russell and Adams on this point for calcium and barium but fails to confirm their views for low excitation potentials. Russell also points out that atoms of even atomic number are present in excess and that the relative abundance suggests a dependence on the periodic law, the abundance being possibly a function of the atomic nuclear structure. Deslandres (*C.R.*, **188**, 21, 669) points out a relation between the frequencies of strong lines in the chromosphere, namely that they are all near to multiples of 1062·5 and that the majority belong to atoms of even atomic numbers.

St. John (*Proc. Nat. Acad. Sci.*, **15**, 789) gives an account of the methods used in identifying the Rowland lines, and the uses made of multiplet relations, pressure groups, excitation potentials, etc. There are still a few strong lines and about 9000 weak lines to be identified. The presence of He^+ 4686 in the chromosphere with a required voltage of 72·6 volts still awaits explanation. St. John also gives (*Ap. J.*, **70**, 160) a list of elements doubtful or unidentified in the Sun and the probable reasons for their absence, and suggests the more helpful laboratory observations to be made. Kothari suggests (*Nature*, **124**, 90) a possible source for faint Fraunhofer lines in the combined effect of Raman scattering and ordinary absorption. He claims a number of coincidences of faint lines with rotation frequencies of CN molecules modified by Raman scattering and absorbed by Ca^+ atoms. S. B. Nicholson and Perrakis (*C.R.*, **188**, 41) have found the D3 line of *He* dark in faculæ near sunspots, especially in areas between spots. The line they have measured is distinct from the atmospheric line at 5875·603A.

Sommer (*Zeits. für Phys.*, **58**, 573) claims to have identified in the Sun certain lines in the spectrum of oxygen and nitrogen arising from interchanges between deep-lying metastable states, lines already identified in the auroral spectrum.

Babcock (*P.A.S.P.*, **41**, 274) announces that he has extended the measured solar spectrum to 11630A, with an accuracy 100 times that of the bolometric data. He gives an account of the devices adopted to get rid of scattered light, notably a filter of neocyanin dissolved in chloroform. Abbot and H. B. Freeman have carried out a bolometric study of the Sun's spectrum from 7727A to 18194A. A vacuum bolometer and 3 prisms were used and much more detail was obtained than in the earlier work.

Minnaert and van Assenbergh (*Zeits. f. Phys.*, **53**, 248) have measured the intensity contours of a number of Fraunhofer lines in the region 4400–4550A. Calculating the total energies of the lines, and assuming them to vary as $\sqrt{N}$, where N is the number of absorbing atoms involved, they find a reasonably consistent set of relations.

The Chromosphere.—Unsöld (*Ap. J.*, **69**, 209) applies Milne's theory of the chromosphere to the contour of the bright H and K lines at the limb, with their central absorption, and comes to the conclusion that random turbulent motions of atoms of Ca^+ with velocities considerably higher than those corresponding to the solar temperature would be consistent with the observations. McCrea (*M.N.*, **89**, 483, and *Nature*, **124**, 442) finds, consistently with Payne's results for stars, a great excess of *H* over Ca^+ in the corona and that only electrical forces could support the hydrogen chromosphere. Turbulence is also adopted by him to explain the density of the hydrogen distribution given by Pannekoek and Minnaert's eclipse results. Woltjer (*B.A.N.*, **5**, 43, 135) suggests an outward motion of the Ca^+ atoms in the chromosphere as adequate to explain Unsöld's contours mentioned above; and from a study of Minnaert's residual intensity in the K line in the light of Milne's theory and Zwaan's computation of transition probabilities for the corresponding emission coefficient, Woltjer constructs a model of the chromosphere where a stationary state is accompanied by a constant outward acceleration of Ca^+ atoms. Woolley (*M.N.*, **90**, 170), applying a scattering formula of H. A. Wilson's, finds that the central intensities of the H and K lines fit best with Eddington's model of the solar atmosphere.

McCrea (*Observatory*, **52**, 267) discusses recent results on multiplet intensities in eclipse spectra and in Davidson's work on calcium multiplets at the limb. Taking into account Unsöld's theory of residual intensity and Milne's theory, he discusses the good accordance with simple multiplet laws in the high chromosphere where small optical depths are concerned and the reason for comparative failure of agreement in the low chromosphere. Davidson's results are in good accord with what wave-mechanics applied to the problem would lead us to expect. Clarkson (*Phil. Mag.*, vii., **1**, 98) compares the theoretical intensities of the multiplets $2^4F–2^4F'$, $2^4F–2^4D$ of Fe^+ with those found in the arc and in the chromosphere by Pannekoek and Minnaert. There is no agreement with theory for the individual multiplets, but there is good agreement when the two multiplets are summed together, save for two lines abnormally weak in the flash and suggesting the action of self-reversal.

Gurney (*Nature*, **123**, 240) suggests that the evidence of daylight observations of the limb when compared with eclipse results is strongly in favour of a sharp upper boundary to the calcium chromosphere, contrary to Milne's theory. D'Azambuja (*C.R.*, **188**, 380) examines the heights of gases in the chromosphere by comparing the diameters of the solar images in spectroheliograms taken in different wave-lengths. He obtains heights in general about one-third the corresponding heights found by Mitchell at eclipses, and results agreeing with Gurney's for Ca^+. Unsöld (*Ap. J.*, **69**, 275) examines the interpretation of spectroheliograms in the light of modern theories of absorption and radiation. His results support the old interpretation that the central portions of the lines come from higher levels in the Sun, and explain the differences between the spectroheliograms from the centre and wings of $H\alpha$ in

terms of the electrical fields to which the atoms are subjected. Evershed (*M.N.*, **89**, 566) finds in the absorption bands of H and K emission lines at 3967·04, 3969·40, 3931·54, 3934·80. The lines originate in a low level in the reversing layer, but above the lowest level for Ca^+ ; they cannot be traced in the upper chromosphere. Buss (*Observatory*, **52**, 365) reports an exceptional chromospheric outburst on November 14, as a large spot group reached the limb.

Prominences.—Royds (*M.N.*, **89**, 258) reports a prominence on 1928 November 19, which remained remarkably compact and bright up to a height of 567,000 miles above the limb, where it was last seen. Upward velocities were measured up to 229 km./sec. Sellers (*Journ. B.A.A.*, **39**, 153) reports an interesting cloudy prominence, like the one of the 1919 eclipse, as seen on 1919 January 19, while Abetti (*Pub. d. R. Univ. d. Firenze*, fasc. No. 45) discusses the rates of growth of a prominence on 1928 May 14, which rose at a varying rate from 50,000 km. to 91,700 km. in $6^h\ 20^m$. The highest velocity, 19 km./sec., was observed at the start. Öhman (*M.N.*, **89**, 479) has suggested from analogy with the polarisation of fluorescence that the bright-line spectra of the chromosphere and prominences might well show evidence of polarisation.

Corona.—Stetson and Andrews have published (*Ap. J.*, **69**, 227) a photometric study of standardised plates of the corona secured by the former in Sumatra in 1926. The intensity law varies from ρ^{-7} to ρ^{-2}, where ρ is the distance from the Sun's centre, as the region examined is taken farther from the Sun's limb. Kienle and Siedentopf (*A.N.*, **235**, 9), by a comparison of the falling-off of intensity of the so-called photographs of the corona, secured by Blunck and others without eclipse, with the rate of falling-off found at eclipses, make it clear that scattered sunlight is the cause of the images secured.

Russell and Bowen (*Ap. J.*, **69**, 196) reject Freeman's identification of the spectrum of the corona with that of argon. Lindsay (*Nature*, **124**, 94) reports that he has examined unsuccessfully for coronal identification the forbidden lines of *Fe*II, *Ca*II, *Ti*II, *Ti*III, *Ar*II, and some lines of *Ti*I. Zessewitsch and Nikonow (*Nature*, **123**, 909) suggest a photo-electric origin for the coronal spectrum, basing their views on the nebular theory of Zanstra. Their views involve the coronal lines being weaker over prominences, a view not supported by objective-prism spectrograms of the corona.

Eclipses.—A number of expeditions were sent to observe the total solar eclipse of 1929 May 9. Most of them observed it through a thin veil of clouds. Preliminary reports on the results obtained have been published as follows :—

Rubel Eclipse Expedition to Takengon in Sumatra. Clear patch of sky throughout totality and stars down to $9^m{\cdot}2$ found on the Einstein plate. Good coronal pictures were secured (Miller, *Pop. Ast.*, **37**, 495).

A neighbouring German expedition under Freundlich stayed behind

for comparison plates for the Einstein effect, but no results have been published. A Dutch expedition at Idi was clouded out.

A Japanese expedition to Penreula in Sumatra secured good images of the corona, but other observations were spoilt by cloud (Yamamoto, *Bull. Ast. Inst. Kyoto Univ.*, No. 155).

Two British expeditions were at Alor Star in Kedah and Pattani in Siam. Photographs of the inner corona were secured at Alor Star only (*M.N.*, **90**, 121).

An expedition from Harvard to Alor Star got a light-curve with an illuminometer: the value 0·15 foot-candle found at mid-totality showed that the corona was unusually bright (Stetson, *Pop. Ast.*, **37**, 183, 370).

An expedition from Tokio to Jitra in Kedah secured photographs of the corona only (Sotome, *Tokio Astron. Bull.*, No. 32), as did also an expedition with an elaborate photometric programme which went to Khoke Bhode in Siam from Kiel under Rosenberg.

A French expedition under the Bureau des Longitudes went from Strasbourg to Poulo Condor. Good coronal pictures were obtained, but it is reported that the Einstein effect will probably not be secured owing to clouds. Photometry of corona was secured with photo-electric cells, the total brightness varying, according to the region exposed, between 0·37 and 0·67 that of full moon. (Danjon, *C.R.*, **189**, 1190; also *C.R.*, **188**, 749.)

An expedition from Hamburg went to Cebu in the Philippines. Photographic and spectroscopic programmes were carried out through thin clouds; the inner corona was well seen (Baade, *A.N.*, **235**, 175, 263).

An expedition from the U.S. Naval Observatory, Washington, to Iloilo in the Philippines observed through light clouds but secured good photographs of the corona (Sollenberger, *P.A.*, **37**, 471; also Waterfield, *Nature*, **124**, 177).

Alter (*A.N.*, **234**, 65) publishes a brief account of the effect of uncertainties in the elements involved on the times of contact and duration of totality of eclipses. Harzer (*A.N.*, **235**, 305) discusses the darkening of the limb of the Sun to be deduced from eclipse results, comparing the theory for stellar eclipses with that for an eclipse of the Sun where the exposed limb subtends a finite solid angle at the instrument. Barabascheff and Semejkin (*A.N.*, **236**, 287) observed the reflected skylight, during the partial solar eclipse of 1928 November 12, with a Bechstein luxmeter and an actinometer. The photometric results agreed well with theory except during the period of brightening, when the sky was almost completely cloudy and the observations gave too much light.

Relativity Displacement.—Evershed (*M.N.*, **90**, 186) has measured the wave-lengths of H and K in the prominences and the chromosphere and gets displacements of +0·0154 and +0·0151 instead of the predicted values of + 0·0081, +0·0083 respectively. He adds that any explanation put forward to account for the discrepancy must apply to

chromosphere and prominences alike. Warga (*Publ. Allegheny Obs.*, **6**, No. 10) finds for the *Mg* triplet at 3830A a displacement less than that required by relativity, and for that at 5170 a displacement greater than the theoretical one. Applying St. John's explanation for the failure of weak lines to show the Einstein effect as being due to the outward flow of low-lying gases, Warga finds that the mean shift of the two magnesium triplets is only one-third of that predicted by St. John.

Solar Radiation.—Juska (*Veröff d. Univ. Sternw. zu Göttingen*, Heft. 7) examines with a photo-electric cell the radiation from the disc up to $\frac{1}{100}$ of the radius from the limb. He finds close agreement with Moll's observations except near the edge, but the general fall from centre to limb is steeper than Schwarzschild's theoretical figure. Heckmann and Siedentopf (*ibid.*, Heft 8) discuss the improvement of the observational results by allowing for the weakening of illumination through atmospheric tremors. The observational results are brought much nearer to the theoretical for most of the disc. For the limb they suggest that total or annular eclipses should be used. Lvoff (*Bull. Soc. Amateur Astronomers, Moscow*) compares Milne's theory of radiative equilibrium for the distribution of monochromatic radiation with Abbot's Smithsonian observations for 1906–8, pointing out the effect of selective absorption. He derives 5960° as the most probable value of the effective temperature of the Sun. Clark (*J.O.S.A.*, **18**, 172) measures the amount of ultra-violet radiation (in the region 3500–2950) in sunlight by the amount of darkening of a screen of zinc sulphide moistened with saturated lead acetate.

Solar Rotation.—Evershed (*M.N.*, **89**, 250) still finds a high rate of rotation from the H and K lines in prominences in 1928, but not so high as in 1927 — $\xi = 16°{\cdot}9$ daily motion instead of 20°. He finds no evidence of polar retardation. Hase and Perepelkin (*A.N.*, **236**, 113), also using H and K lines in prominences at a height of 10,000 km., get $\xi = 15°{\cdot}1 \pm 1°{\cdot}2$, while for $H\epsilon$ they get $\xi = 14°{\cdot}0 \pm 1°{\cdot}4$. Evershed's average height was more than twice as great.

Corbu (*A.N.*, **234**, 321) suggests a dynamical explanation of the equatorial acceleration, arising from the gaseous nature of the solar atmosphere. Notuki (*Proc. Physics-Math. Soc. of Japan*, **11**, 102) examines the combined effect of depth parallax and refraction in the solar atmosphere on the determination of solar rotation from spots and finds it almost negligible.

Periodicity.—Rosseland (*Norske Vid. Akad. Oslo Mat. Nat. Kl.*, 1929, No. 6) suggests that the solar periodicity is controlled by large-scale internal circulating currents and may be an "activity period" covering the change from a laminar flow with no irregularities to a highly disturbed condition of eddies, and back again. He suggests that where such an activity period was near to a free vibrational period of a star, as is not the case with the Sun, pulsations might be set up.

Taffara (*Mem. Soc. Astron. Ital.*, **4**) discusses the solar activity for the period 1877–1928 and notes that high and low maxima alternate. He gets 6·728 years as the average interval from maximum to minimum and 4·313 years for the reverse step. S. B. Nicholson and Sternberg (*P.A.S.P.*, **41**, 277) point out that the recent maximum was broad with three peaks; that of 1926 was for areas and depended mainly on one huge spot group. Numbers gave two peaks in 1927, 1928. Göschl (*A.N.*, **234**, 406) ventured to make a forecast of solar activity in 1929 from the influence of outer planets.

Sunspots.—Sekiguti (*Bull. Central Met. Station, Tokyo*, 1921) discusses the formation of spot vortices in terms of terrestrial vortices. He suggests for the high vortices the presence of sloping temperature inversion layers and that these work down to deep vortices below. He finds that isolated regular spots have a westward motion in their early stages and again near the end of their lives.

Magnetic Fields.—Ross Gunn (*Ap. J.*, **69**, 287, and *Phys. Rev.*, **33**, 614, 832; **34**, 335) discusses the maintenance and regeneration of magnetic fields owing to drift currents set up by the spiral paths of ions under the influence of crossed magnetic and gravitational fields. Cowling (*M.N.*, **90**, 140) criticises Ross Gunn's attempt along these lines and also Chapman's earlier attempt along very similar lines to explain in this way the limitation of the Sun's magnetic field. Unless temperature gradient is taken into account, he maintains that the effects found by the earlier writers are illusory. Chapman (*Nature*, 1929 July 6, Supplement) gives a general review of the problems of solar and terrestrial magnetism and a detailed account of his views on the formation and limitation of the Sun's magnetic field, views which Deslandres (*C.R.*, **189**, 413) claims to be in complete accord with his own estimate of a weak magnetic field of the Sun in high layers (distinct from the field investigated at Mt. Wilson) indicated by the curvature of prominences and by the polar plumes of the corona.

Terrestrial Phenomena.—Chapman has produced the second report of the Commission of the International Research Council on *Solar and Terrestrial Relationships.* In addition to a programme of proposed research or extension of existent activities, this report embodies a number of valuable memoranda upon such questions as magnetic storms and daily variations, wireless transmission, the aurora, the ozone content in the atmosphere, and the light of the night sky. The report is too much packed with interesting material to make a detailed account practicable. Gehlinsch (*Acta Univ. Latviensis, Riga*, **19**, No. 3) examines the connection between magnetic storms and sunspots by considering the magnetic disturbances for 5 days each side of central transit of isolated spots appearing alone on the Sun's disc. All but 2 out of 70 spots examined were accompanied by magnetic disturbances of sorts, the spots rich with faculæ being most active: the spot's latitude and distance from the meridian did not seem to be

decisive ; spots were more active on the east limb or when the spot was 2·5 days on either side of the central meridian. Tangential ejection of corpuscles with asymmetry east and west of spots is suggested. Chapman and Ferraro (*M.N.*, **89**, 456, 470) discuss the electrical state of a cloud of ions and electrons ejected from the Sun, from a disturbed atmosphere supported by radiation-pressure. The ratio of charge to mass in an ionised cloud is too low to account for the angular radius of the auroral zone. Chapman also suggests that the velocity and density of the stream could possibly be checked by observing a displaced K line against a background of an undisturbed region of the Sun. Wasserfall suggests (*Norske Vid. Akad., Oslo, Geof. Pub.*, **5**, No. 10) that temperature records at Oslo in 1916, when solar activity was largely concentrated round one meridian, show a well-defined period of $27^{d}\cdot3$, with changes of phase accompanying changes in the Sun's longitudinal distribution of activity. A short period of $4^{d}\cdot0$ was also present, agreeing with Abbot's figures for a short-period variation of the solar constant. Stetson and Pickard (*Pop. Ast.*, **37**, 388) find a correlation between radio reception and sunspot activity. Single spots give increased ionisation and bipolar spots diminished, as though electrons emitted from a double spot are more closely bound to the Sun.

Störmer (*Nature*, **123**, 82, 868 ; **124**, 263) compares the spectrum of the high aurora lit by the Sun's rays with that of the low aurora in a dark part of the sky. He finds in the former that the line at 5577A is much fainter relative to the lines of ionised nitrogen at 3914, 4728. Vegard (*ibid.*, **124**, 947) regards the question as a mere altitude effect independent of direct solar action. R. W. Wood suggests that the ozone should be least in a polar night sky, a conclusion that Dobson and Rosseland reject. The least ozone is to be found in the tropics (*ibid.*, **123**, 644, 712, 761). Riddle (*J.O.S.A.*, **18**, 442) states that the lower wave-length limit of solar radiation for all-day exposures changes from 303$\mu\mu$ in December to 296$\mu\mu$ in June.

Fowle (*Smithsonian Collections*, **81**, No. 11) shows that the ozone absorption from a high layer varies very little with sunspots but has a periodic seasonal change, while another layer of ozone was formed at a lower level by the bombardment of electrical particles from the Sun, and this depended mainly on sunspot activity. The double agency was reflected in the magnetic data. Jones (*R.S. Proc.*, **801**, A, 246) examines the variations in light of the night sky at the Cape and Canberra (*Memoirs of Commonwealth Solar Obs., Mt. Stromlo*, No. 1), and finds connections between sunspot frequency, variations in the magnetic field, non-polar auroræ and the brightness of the night sky. The seasonal fluctuations are in opposite phase in the north and south hemispheres. The evidence for diurnal periods, sunset to midnight, is still uncertain. Unakar (*Nature*, **124**, 11) states that if the annual means of pressure are smoothed by taking overlapping means of 11 successive years, high positive or negative correlations result at most stations, with a similarly smoothed sunspot curve.

Miscellaneous.—Reference must be made here to the appearance

of Bd. IV. of the *Handbuch der Astrophysik*, with articles on Solar Radiation and Temperature by Bernheimer, on Solar Physics by Abetti, and on Eclipses by Mitchell. F. J. M. S.

Stellar Spectroscopy in 1929.

Theoretical Investigations.—Professor Eddington has published a paper on the formation of absorption lines in which he brings out the difference between absorption in a stellar atmosphere which is in approximate thermodynamic equilibrium, and the absorption observed when, for example, a beam of light is passed through a sodium flame.

Professor Milne's Bakerian lecture to the Royal Society on the structure and opacity of a stellar atmosphere is a most valuable contribution and forms a comprehensive summary of our knowledge of the problem of stellar atmospheres at the present day. There is first of all an analysis of the thermal structure of a stellar atmosphere, followed by the determination of the photospheric opacity, and, in conclusion, the various applications of the theory to, for example, the determination of the number of atoms engaged in producing a line. There is also an interesting discussion of the imperfections of the theory.

Professor Milne has also pointed out that if the opacity in a stellar atmosphere varies as the electron pressure, then if we plot the number of atoms in any state down to a given optical depth against the temperature for different values of the surface gravity, the curves all merge together into one and the same curve, a little on the high temperature side of the maximum.

Classification.—The recent spectroscopic discovery of isotopes of carbon and oxygen has borne astrophysical fruit in the identification of some hitherto unknown bands in N stars by R. F. Sanford, who has shown that bands at 4745 and 4751 are due to carbon compounds containing carbon of atomic weight 13 and 14 respectively.

Several detailed investigations of particular spectra have appeared during the year; in particular may be mentioned Dunham's study of the spectrum of α Persei and Merrill's research on the spectrum of B.D. + 11° 4673, where he finds that the oscillations of the bright lines of several elements show extraordinary differences. H. H. Plaskett has published a study of the composite stellar and nebular spectrum of Z Andromedæ.

C. T. Elvey and R. S. Zug have found that the absorption band recorded in stellar spectra at Yerkes at 4200 is due to absorption by the glass of the objective.

A valuable contribution is a spectroscopic Durchmusterung of a Kapteyn field in the southern sky.

N. T. Bobrovnikoff finds that the spectra of the minor planets, while consisting on the whole of reflected sunlight, have a continuous background like that of comets near perihelion.

Spectrophotometry.—This region of investigation continues to prove a rich mine of new information. C. T. Elvey, in investigating the contours of helium lines in stellar spectra, finds that axial rotation is indicated by the dish-shaped contours in some of the 28 stars measured. A comparison of his results with Milne's theory indicates that the absorption coefficient varies with the pressure, rather than that it is constant.

O. Struve and C. D. Higgs have measured the contour of the K line for four A-type stars and find that α Lyræ agrees with Unsöld's formula; for α Cygni the agreement is not so good, and for α Aquarii and α Ophiuchi the lines are wide and shallow and cannot be fitted to the formula at all.

Miss Payne and Miss Williams, in a study of the hydrogen and calcium lines in stellar spectra, find that the data are not in accord with the predictions of Milne's unmodified theory. They devote particular attention to the changes of intensity of a line at various levels.

It is worth remarking that this procedure, namely, the study of a line at a given optical depth in a star, is an important departure from the former practice of concentrating attention on central intensities, and is made possible and fruitful by improvements both in theory and experimental technique.

Messrs. Greaves, Davidson, and Martin have published a new list of colour temperatures of 24 stars, suitable for use as spectrophotometric standards, using their method of a prism crossed by a grating. B. P. Gerasimovič, referring to the remark of these authors that yellow B stars have strong cosmic K lines, and that the reddening is due to interstellar calcium, concludes against this and suggests that it is an absolute magnitude effect.

An attempt to render available for photometric measurements the vast store of slit spectra taken in the past without photometric standard comparison spectra has been made by F. S. Hogg. His method is to use the known relations between the intensities of multiplets, principally those of the iron arc, to calibrate the scale of densities in terms of intensity. Very satisfactory results have been obtained, and a test upon calcium lines of three M stars gives good agreement with the results obtained from standardised plates.

N. W. Storer, in a study of the continuous spectra of giant and dwarf stars, reaches the conclusion that no colour-index involving only the visual spectrum can distinguish a giant from a dwarf.

C. G. Abbot has continued at Mount Wilson his measurements of the energy spectra of the stars, giving curves for 18 stars and 2 planets. He has developed a new and improved radiometer, pressing natural history into the service of astrophysics for the purpose, for the vanes of his new radiometer are made out of flies' wings.

Radial Velocities.—A valuable and extensive addition to our knowledge of radial velocities has been made by the Mount Wilson observers in the publication of a list of the radial velocities of 741 stars.

C. D. Perrine, from an examination of the dependence of radial

velocity on spectral condition, suggests that expansion and contraction of the stellar atmosphere is necessary to account for the observations.

Interstellar Calcium.—Dr. Struve has continued his work on the fixed calcium lines and now has found it possible to determine stellar distances from the intensities of detached K lines. This constitutes an inversion of his previous work on the correlation between intensity and distance, and is virtually a discovery of an absolute magnitude spectroscopic criterion. He has determined the distance of the cluster in Perseus from the intensity of the calcium lines.

Dr. Struve has also investigated the systematic speed of interstellar calcium clouds and finds a correlation with distance.

Y. Öhman has discussed the possibility of observing an emission spectrum in the night sky from the calcium substratum in the galaxy. He concludes that the principal pair H and K are not to be expected, but the forbidden pair 1S–3D ($\lambda\lambda$ 7293 and 7326) might be strong enough to show.

J. H. Oort finds evidence supporting Struve's conclusion concerning the intensities of the K line in early type stars, that there is no absolute magnitude effect.

Miscellaneous.—Several investigations have had as their object the investigation of conditions in stellar atmospheres by such means as the broadening of spectrum lines by the Stark effect due to the random fields of neighbouring atoms. It is found, for example, by Struve, that the Stark effect is more pronounced in dwarfs than giants, and he has developed a method of determining comparative absolute magnitudes of B-type stars by the relative intensities of the forbidden helium line, λ 4470, and the ordinary line of helium, λ 4472.

G. Shajn and O. Struve have made a test of the rotational effect on stellar spectra by using spectroscopic binaries, whose periods of rotation may be presumed to be the same as their periods of revolution. Satisfactory results are obtained, and the authors are in agreement with J. A. Carroll that central intensities of lines provide a more sensitive criterion of rotation than line widths.

A useful communication is made by P. V. Neugebauer dealing with a method of development of photographic plates to avoid effects due to halation and spreading of the image.

C. S. Beals, from a study of the nature of Wolf-Rayet emission, comes to the conclusion that it is due to the ejection of high-speed atoms by selective radiation-pressure. D. H. Menzel, in a review of the properties of Wolf-Rayet stars, suggests that they are O-type stars surrounded by a gas shell expanding radially.

E. A. Kreiken has brought forward evidence which he believes leads to the conclusion that spectroscopic binaries are dwarfs in general, but W. J. Luyten, in a critical examination of Kreiken's papers, refutes this on technical grounds, principally concerning the value taken by Kreiken for the average value of the sine of the inclination of the orbit.

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O. Struve, "Stark Effect in Stellar Spectra," *Ap. J.*, **69**, 173, 1929.
———— "Pressure Effect in Stellar Spectra," *Ap. J.*, **70**, 85, 1929.
———— "Stark Effect as a Means of Determining Comparative Absolute Magnitudes," *Ap. J.*, **70**, 237, 1929.

Proper Motions.

The last Council note dealing with this subject appeared as far back as 1919. In the intervening years a vast amount of work has been done in determining, discussing, and interpreting stellar motions, and it is therefore impossible to give here more than a brief outline of a small selection of investigations dealing almost exclusively with proper motions. For this reason, two important developments of recent years, which are based to a large extent on the study of radial velocities, can

only be mentioned here in passing ; they concern, firstly, the problem of galactic rotation for which most of the observational evidence has been presented by J. H. Oort and J. S. Plaskett, and, secondly, the problem of the high-velocity stars studied by G. Strömberg and Oort. It will be convenient to subdivide recent work into the following categories :—(*a*) General Investigations, (*b*) Systematic Motions of Faint Stars, and (*c*) Special Problems.

(a) *General Investigations.*—For the bright stars Boss's *Preliminary General Catalogue* still remains the standard work of reference. The completion of the San Luis Catalogue of 15,333 stars marks an advanced step towards the formation, in the near future, of a *General Catalogue* which will give the positions and proper motions of at least 30,000 stars distributed over both celestial hemispheres.

Schorr's *Eigenbewegungs-Lexikon*, to which appendices are added from time to time, is a catalogue of the proper motions of B.D. stars according to the most recent determinations by meridian circle or photography.

Volume iv. of *Yale Observatory Transactions* contains the proper motions of stars in the zone + 50° to + 55° ; the motions are based on the Astronomische Gesellschaft positions (epoch 1876) and on positions determined by F. Schlesinger 40 years later with his specially designed short-focus camera.

The first of the *Carte du Ciel* zones to be rephotographed is the Greenwich zone from + 64° to + 71° (*Greenwich Astrographic Catalogue*, vol. v.) ; the interval on which the proper motions are based is about 30 years. One or two other observatories have already begun the rephotographing of their zones for the purpose of measuring the proper motions of the faint stars showing on their plates.

From time to time, lists of stars with large proper motions are published by various observatories—these are mainly of interest to parallax observers.

The Boss system of proper motions is of such fundamental importance that it is very necessary to investigate the possibility of systematic errors in the proper motions. An early paper (1922) on this subject by Kapteyn is : " On the Proper Motions of Faint Stars and the Systematic Errors of the Boss Fundamental System " (*B.A.N.*, **1**, 69). From a thorough investigation of the available material, Kapteyn concluded that the most serious systematic error occurred in declination and that the appropriate correction to Boss's annual proper motions in declination could be represented by the term

$$+ 0''{\cdot}0130 \cos \delta.$$

In this paper, Kapteyn also suggested a method for determining the secular parallax of 10th or 11th magnitude stars (normally the magnitudes of the comparison stars used in parallax measures). The measurement of a parallax plate of a Boss star gives, in addition to the value of the star's parallax, the relative proper motion of the Boss star with respect to the group of comparison stars selected. The difference between this relative proper motion and the absolute proper motion as

given in the *P.G.C.* yields the parallactic motion of the comparison stars. In this way, the secular parallax of these stars can be statistically derived.

P. J. van Rhijn and P. van de Kamp (*B.A.N.*, **1**, 209) continue the investigation of the systematic error in declination, following mainly the lines of Kapteyn's work. Their value of the correction is $+ 0''{\cdot}006 \cos \delta$, rather less than half of that found by Kapteyn.

A paper by H. Raymond, entitled "The Corrections to the Declination System of Boss's P.G.C." (*A.J.*, **36**, 129), contains an exhaustive research into the systematic differences in the proper motions of stars, arranged according to declination, between the important catalogues of the past and the *P.G.C.* It might seem that a long series of meridian observations made at a particular observatory with the same detailed methods of reduction ought to give reliable proper motions even although the positions might be in error by presumably constant amounts. However, Raymond shows from an examination of the catalogues of Pulkowa, Greenwich, and the Cape that the suggested homogeneity does not really exist. Raymond's final corrections to the Boss proper motions in declination are given at intervals of 5° in the declinations; these values do not fit a formula of the type $G \cos \delta$.

In a paper, "On the Solar Motion Problem" (*A.J.*, **36**, 138), R. E. Wilson expresses the opinion that the assumptions involved in Kapteyn's corrections of the form $G \cos \delta$ are untenable. As he remarks, investigators have devoted most of their efforts to the determination of the value of G rather than to inquiries into the validity of the proposed form for the corrections. Wilson's work concerns the determination of the solar apex from a homogeneous set of nearly 3000 stars for which proper motions and radial velocities are known. Solutions were made by Bravais's method and it was found that Raymond's corrections (already referred to) are quantitatively sufficient to bring together the co-ordinates of the solar apex as derived separately from the proper motions and the radial velocities. Raymond's results for the solar motion, referred to the bright stars concerned, give the co-ordinates of the apex to be 271°, + 27° and the solar motion, 19·0 kms. per second, all in good agreement with the recent values from the Lick radial velocities (*Lick Publications*, vol. xvi.).

B. Boss and H. Jenkins, in *A.J.*, **37**, 173, compare the Albany and San Luis declination system with the *P.G.C.* Identical stars have been observed at these stations, one of which is north and the other south of the equator, with the same instrument and, as regards the great majority of observations, by the same observers. The material used is consequently very suitable for the investigation under consideration. The authors tabulate the corrections to the *P.G.C.* at intervals of 5° in declination from pole to pole and compare their results with Raymond's corrections.

In a paper, "On the Systematic Errors in the Proper Motions of Boss's System" (*B.A.N.*, **5**, 1), B. J. Bok makes a further contribution to this subject, using the method adopted by van Rhijn and van de Kamp already mentioned. He introduces an additional refinement by correct-

ing the proper motions for the galactic rotation as determined by J. H. Oort and J. S. Plaskett. Although there is now no doubt as to the phenomenon of galactic rotation, the same cannot be said with complete confidence as to the actual numerical values used in correcting the proper motions. However, Bok concludes that Raymond's system of corrections is substantially correct.

(b) *Systematic Motions of Faint Stars.*—Photographic plates, taken 10 to 30 years ago, form the foundation for the measurement of proper motions of faint stars. The usual practice now is to rephotograph the parts of the sky concerned, placing the plate in the telescope with the film away from the object-glass so that the starlight passes through the plate-glass before incidence on the film. The old and the recent plates can then be placed film to film and the differences in the positions of a pair of images can thus be measured without the intermediary of a réseau. The proper motions derived in this way are relative to the particular reference stars selected, but by utilising the best available values of the parallactic motions of such stars the relative proper motions of all the stars can be converted into absolute proper motions. It is unusual to find for any region of the sky a sufficient number of stars with well-determined meridian proper motions with which to make the reduction from relative to absolute proper motions ; in any event, it would appear that the parallactic method is less liable to introduce systematic errors than the method of utilising meridian proper motions.

Some years ago, several investigators showed that in individual regions the motions of the faint stars exhibited the same systematic features as the bright stars which Kapteyn first interpreted in terms of the two-streams theory. Amongst the principal investigations dealing with the analysis of the systematic motions of faint stars in representative regions of the sky may be mentioned the following :—O. J. Lee (*Yerkes Publications*, vol. iv., part 4), who discussed the proper motions of 1041 stars in zone + 45° of Kapteyn's Selected Areas ; G. H. ten Bruggencate (*B.A.N.*, **3**, 35), who utilised the proper motions of 4245 stars measured at the Kapteyn Laboratory at Groningen : the majority of these stars are in the zone of − 45° declination ; W. M. Smart (*M.N.*, **87**, 122, and *Cambridge Observations*, vol. xxvi.), who discussed the proper motions of 3029 stars ; V. Nechvile (*Publications de l'Observatoire de Prague*, No. 4), who measured and discussed the proper motions of 3802 stars derived from plates taken at Paris Observatory ; Sir F. W. Dyson (*Greenwich Astrographic Catalogue*, vol. v.), who investigated the proper motions derived from the rephotography of the astrographic zones + 64° to + 71°. In all these investigations the phenomena of star-streaming were exhibited amongst the faint stars concerned. The determination of the drift-apices has been made by the authors mentioned. In addition, A. S. Eddington (*M.N.*, **87**, 138) has treated the Cambridge proper motions by the analytical method which he devised in 1908 (*M.N.*, **68**, 588) ; Smart (*M.N.*, **88**, 144) has derived the constants of the star-streams from the Groningen proper motions ; and Smart and H. E. Green (*M.N.*, **89**, 147) have made a similar analysis of Nechvile's proper motions. The following may be regarded as the mean results for

the faint stars, to which are added in parentheses Eddington's results derived from the proper motions of the bright Boss stars.

	Drift I.		*Drift II.*	
R.A. of Apex	90°	(91°)	280°	(288°)
Dec. „	− 8°	(− 15°)	− 62°	(− 64°)
Velocity	1·40	(1·52)	0·90	(0·86)

Solar Motion.

R.A. of Apex	275°	(267°)
Dec. „	+ 41°	(+ 36°)
Velocity	0·72	(0·91)

Vertex of Star-Streaming.

R.A.	91°	(94°)
Dec.	+ 19°	(12°)
Velocity	1·84	(1·87)

Several investigations into the mean parallax of stars used as comparison stars in the determination of stellar distances have recently been made. M. S. Kovalenko (*A.J.*, **37**, 149) discusses this problem of the 10th-magnitude stars from measures made on M'Cormick parallax plates. He also derives the co-ordinates of the solar apex with reference to these stars. In *A.J.*, **37**, 191, van de Kamp makes another contribution to this subject. The dependence of the secular parallax s (for 10th-magnitude stars) on the galactic latitude b is found to be well represented by the formula

$$\log s'' = - 1{\cdot}700 - 0{\cdot}252 \cos 2b.$$

van de Kamp's work confirms the corrections made by parallax observers in the reduction of relative to absolute trigonometrical parallaxes. The solar motion in this work is assumed to be 20 kms. per second. In *L.O.B.*, No. 374, the same author has derived the radial velocities of 105 stars between visual magnitudes 9 and 10, from which the solar motion is found to be 18 ± 2 kms. per second. This result appears to show that there is probably little difference between the magnitude of the solar motion as derived from the bright stars and the amount derived from the fainter stars here considered. In *Ap. J.*, **64**, 50, F. H. Seares had proposed a formula

$$V = 12{\cdot}9 + 1{\cdot}21m,$$

giving the value of the sun's velocity V with respect to groups of stars of magnitude m, but van de Kamp's work does not support this.

(c) *Special Problems.*—In his George Darwin Lecture (*M.N.*, **89**, 660) E. Hertzsprung has described his exhaustive researches on the Pleiades. The annual proper motion of the bright cluster stars is 0″·048 in position angle 156°, and from the determination of the proper motions of stars within 1° of Alcyone derived from numerous photographic plates, Hertzsprung has been able to separate the faint cluster stars from the

general stellar background. His investigation has been pushed to stars as faint as the 16th magnitude, and, as far as the detection of the physical members of the Pleiades is concerned, the limit does not appear to be reached even at this faint magnitude. So far, 150 members of the cluster have been found within 1° of Alcyone. Hertzsprung has also derived the colour-indices of the cluster stars and, plotting colour against magnitude, has demonstrated in the most conclusive manner the reality of the " main series " in the Hertzsprung-Russell diagram.

In *B.A.N.*, **1**, 37, Kapteyn and van Rhijn investigated the proper motions of galactic Cepheids from which they derived the mean parallax of these stars. Dividing the stars into two classes (Class I., for which the light-periods are around half a day, and Class II., for which the periods exceed $1\frac{1}{2}$ days), the authors found from a discussion of the photographic and meridian proper motions of 14 stars of Class I. that the average parallax is $0''{\cdot}0065$, which is about seven times the value used by Shapley in his work on globular clusters. The mean parallax of 11 stars of Class II. is, however, in good agreement with Shapley's value. As the cluster variables are mainly of Class I., Kapteyn and van Rhijn's investigation appeared to show at the time that Shapley's estimates of the distances of the globular clusters were about seven times too great. However, if it be granted that the stars in the two classes form a progressive series, the small parallaxes of the Cepheids as used by Shapley are supported by the small parallaxes of Class II. stars found by the authors. The question of the distances of the galactic Cepheids is, of course, of paramount importance in the exploration of the distant regions of the universe, and several observatories are now devoting attention to the accurate measurement of the proper motions of these stars.

In two papers (*M.N.*, **88**, 567, and **89**, 93), W. M. Smart has been considering the proper motions of stars in relation to their space distribution. Some years ago F. W. Dyson (*M.N.*, **73**, 334 and 402) and A. S. Eddington (*M.N.*, **73**, 346) suggested as a working hypothesis for the volume density of stars at a distance r the formula

$$\frac{A}{r^{\gamma}} e^{-h^2k^2r^2},$$

and the former showed by considering a special region of the sky in which the systematic motions of the stars occurred in declination only, that the observations were in substantial agreement with the implications of the formula. In the first paper, Smart has generalised the theory so that it can be applied to any part of the sky. The theory gives a relation between the drift velocities obtained from the analysis of the frequency-distribution of stars with proper motions restricted to values exceeding a definite amount and the true drift velocities obtained when this restriction is not imposed. Theoretical expressions are also obtained giving the proportion of stars in a drift with proper motions exceeding any value μ. In two papers, " The Analysis of Nechvile's Proper Motions " (*M.N.*, **89**, 147) and " The Moving Foreground of the Large Magellanic Cloud " (*M.N.*, **90**, 112), the theory is tested, so far with satisfactory results. The proper motions used in the second of these

papers were derived by W. J. Luyten from photographs taken with the Bruce telescope (*Harvard Circular*, Nos. 326 and 328). The constant k of the formula has been found to vary with galactic latitude, as might be expected from the results of other work on the space-distribution of stars in the galaxy. In order to apply the theory to stars at much greater distances it is necessary to have accurate values of the smaller annual proper motions (between $0''{\cdot}1$ and $0''{\cdot}3$) in addition to those exceeding $0''{\cdot}3$ which, frequently, are alone measured or given in proper motion catalogues.

In a paper entitled " The Star-streams " (*A.J.*, **39**, 143), J. Schilt calls attention again to the second harmonic terms occurring in the proper motions (these terms depend on sin 2α, cos 2α, cos 2δ) and also in the radial velocities. Schilt points out that Schwarzschild's ellipsoidal hypothesis cannot account for these terms in the stellar motions nor can the two-streams theory if the mixture of the two streams is constant all over the sky. His conclusion is in favour of the two-streams theory with non-uniform mixture. Schilt has further evidence (the paper has not yet been published) in favour of the existence of separate streams in contradistinction to the rival ellipsoidal theory.

W. M. Smart has a theoretical paper, " On Schwarzschild's Ellipsoidal Theory " (*M.N.*, **89**, 105), in which the formula for the space distribution of the stars (*v.* page 462) is introduced into the analysis. The object is to investigate the distribution and proportion of proper motions exceeding any given amount and to find some criterion which will enable the observations to discriminate between the two-streams theory and the ellipsoidal theory. This criterion appears delicate enough if and when accurate proper motions are available in greater numbers in selected regions of the sky. W. M. S.

List of Public Institutions and of Persons who have contributed to the Library, etc., since the last Anniversary.

(*Institutions exchanging publications with the R.A.S. Library are omitted from the list, in order to economise in printing.*)

Abbadia, Observatoire.
American Association of Variable Star Observers.
Baltic Geodetic Commission.
Belgrade, Observatoire astronomique de l'Université.
Bern, Schweizerische Geodätische Kommission.
British Association for the Advancement of Science, Seismology Committee.
Canada, Geodetic Survey.
Carnegie Institution of Washington.
Commission Internationale des Longitudes par T.S.F.
Danzig, Naturforschende Gesellschaft.
Florence, Osservatorio Ximeniano dei PP. Scolopi.
Geneva, Société astronomique Flammarion de Genève.
Genoa, Istituto Idrografico della Regia Marina.
Havana, Secretaria de Agricultura, Comercio y Trabajo.
Helsingfors, Finnisches Geodätisches Institut.
Hyderabad, Nizamiah Observatory.
India, Meteorological Department.
International Astronomical Union.
Kharkov, Astronomical Observatory.
Kyoto, Astronomical Institute of the Imperial University.
Lembang (Java), Bosscha-Sterrenwacht.
Lemberg (Lwów), Observatorium der Technischen Hochschule.
Lourenço Marques, Observatorio Campos Rodrigues.
Louvain, Laboratoire d'Astronomie et de Géodésie de l'Université.
Mauritius, Royal Alfred Observatory.
Mizusawa, International Latitude Observatory.
Moscow, Society of Amateur Astronomers.
Nantucket, Maria Mitchell Association.
Netherlands Indies Science Council.
Nishni-Novgorod, Verein von Freunden der Physik und Astronomie.
Paris, Société Philomatique.
Poona, Meteorological Office.
Rugby, Natural History Society.
Tachkent, Université de l'Asie Centrale.
Talence, Observatoire.
Tiflis, Geophysikalisches Observatorium Georgiens.
Tokyo, Earthquake Research Institute of the Imperial University.
Tokyo, National Research Council of Japan.
Tokyo, Physico-Mathematical Society of Japan.
Warsaw, Institut d'Astronomie Pratique de l'Ecole Polytechnique.
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ADDRESS

Delivered by the President, Dr. A. C. D. Crommelin, on the award of the Gold Medal of the Society to Dr. John Stanley Plaskett, for his valuable observations of Stellar Radial Velocities, and the important conclusions derived from them.

The medal this year is conferred not for any single outstanding result, but in recognition of the high merit of a long series of researches, extending over a quarter of a century, and marked throughout by a painstaking striving after the highest accuracy attainable, combined with an alertness in discerning problems of stellar motion and stellar physics to which the powerful observational means available might most suitably be applied.

Dr. Plaskett's name became well known to astronomers soon after he joined the staff of the Dominion Observatory, Ottawa, in 1905. The Director, Dr. W. F. King, placed him in charge of the Department of Astrophysics, his instrument being a 15-inch refractor by Brashear. The Ottawa Observatory had only just been completed, as a result of persevering representations to the Canadian Government on the part of Dr. King and Dr. Otto Klotz, which had continued since 1888. It is a testimony to the high reputation gained by the Ottawa Observatory in the first few years of its existence that the larger outlay involved in the foundation of the Victoria Observatory was granted after a very small delay.

The spectroscopic work was practically limited to stars not fainter than the fifth magnitude, and even for these an exposure of an hour was necessary. The aim was not so much to discover new spectroscopic binaries as to obtain sufficient observations of those whose variable radial velocity had been already detected, and to deduce reliable orbits from the resulting measures; a programme was arranged in conjunction with other observatories doing similar work, so as to avoid needless duplication; a few new cases of variable velocity were detected—for example, a small oscillation was found in the radial motion of Rigel, though it is not certain that it arises from orbital motion.

Careful observations were made of Mira Ceti at the unusually bright maximum of 1906 December. The line $H\beta$ was certainly bright, which had not been the case at some previous maxima; $H\epsilon$ was not seen; the titanium bands were prominent; it was deduced that the bright hydrogen lines gave a velocity of recession 15 km./sec. less than the absorption lines.

We must regard as one of the most valuable features of this work at Ottawa the great experience that it gave to our medallist regarding the various errors to which spectroscopic observations are liable, and the best means of eliminating them. One source of trouble was found to be the bad figure of the correcting lens; this lens was placed 32 inches inside the focus of the refractor, its object being to equalise the focal

length for light of different colours ; this lens was found to suffer from spherical aberration ; a new lens, whose surfaces departed from the spherical form, was designed by Professor Hastings, and made by Dr. J. A. Brashear ; it shortened the exposure times by 30 per cent.

Plaskett laid down the following rule for the position of the correcting lens : " It must be so placed that the dispersion produced by it is exactly equal and opposite to that given by the atmosphere." He had noticed that the violet region in a certain spectrum was too weak, and found that it could be remedied in this manner.

Flexure in the spectroscope was another trouble ; it was alleviated by the insertion of stiffening rods ; but in 1909 a new spectroscope, of much greater rigidity, and embodying some features suggested by our medallist, was acquired. He gratefully acknowledged the readiness shown by Dr. King to carry out his suggestions. He noticed the importance of making the jaws of the slit terminate in knife edges. This was not the case at first, the result being increased difficulty in focussing and trouble through reflection from the sides of the slit. He made investigations on the best width of slit to employ ; he found that the average star-image at the slit was about 2″ broad ; originally he employed a slit width of 1″ only, but experiments showed that widening it to 2″ notably shortened the exposure-time, without any sensible diminution in the accuracy of the measures ; further widening, however, gave a rapid falling off in accuracy. I give a few notes on some of the stars for which orbits were found at Ottawa.

ϵ Ursæ Minoris is of the fifth magnitude, which is the faintest that can be conveniently observed at Ottawa ; a satisfactory orbit was, however, deduced, using observations made by Professor Campbell in 1897 and 1899 to improve the period, which is 39·482 days.

θ^2 Tauri has a period of 140 days, with traces of the second spectrum ; this star belongs to the Taurus moving cluster, so its distance and radial velocity are known ; the value of the radial velocity found at Ottawa, + 43 km./sec., is in fair accord with that deduced by Boss from the cluster motion, which was + 40·5.

ϕ Persei has attracted a good deal of attention from the peculiarities of its spectrum ; at Ottawa it was noted that the spectrum was in part emissive, and that it appeared to vary in character according to the phase in the orbit ; there was also an unexplained hump on the descending branch of the velocity curve.

Spectroscopic determinations of the solar rotation were also made at Ottawa, and formulæ deduced for the daily angular motion in different latitudes. Our medallist examined the suggestion that atmospheric scattering of light by haze might affect the results, since each region of the sun would have some light from other regions superposed upon it ; his conclusion was that no serious error was likely to arise in this manner.

He also made a useful study of the most suitable glass for prisms ; he noted that the dense flint glass used in some of the prisms had a yellow tint, and had strong absorption from λ4000 downwards ; a baryta light flint glass was found to be much better ; the exposure

times were found to be reduced in the ratio of 100 to 65 at H_γ, and of 100 to 12 at H_ζ.

Dr. Plaskett had for long entertained the dream of obtaining a telescope of larger aperture; this dream was intensified as a result of his visit to Mount Wilson to attend the meeting of the Solar Union in 1910. During that meeting Professor Campbell invited co-operation in obtaining the radial velocities of stars fainter than the fifth magnitude; he had himself obtained observations for a complete catalogue down to that limit. No one actually volunteered at the meeting, but our medallist, who had been impressed by the fact that the 60-inch reflector at Mount Wilson could obtain in five minutes spectra of fifth magnitude stars that needed an exposure of over an hour at Ottawa, was stirred by the hope that Canada might distinguish herself among the nations by erecting a giant reflector to be devoted to spectroscopic research. On his return to Ottawa he laid this bold suggestion before Dr. W. F. King. He at once endorsed the idea with enthusiasm, and from that time up to the realisation of the scheme gave his active support and advice.

A meeting of the Astronomical and Astrophysical Society of America in the summer of 1911 passed a resolution commending the work of the Ottawa Observatory, and urging the desirability of a larger telescope. This was transmitted to the Minister of the Interior, but a change of Government followed and delayed the matter. In 1912 May the Royal Society of Canada endorsed the scheme, and drew up a strong memorial, embodying letters of commendation from the leading astronomers of Europe, including our own Astronomer Royal; this was forwarded to the Canadian Premier. Dr. Roche, the Minister of the Interior, gave it his support, and the cause was won. Dr. Plaskett expressed his warm gratitude to all, both Astronomers and Ministers, who had lent their support in converting his bold dream into reality.

Besides the grant for the Observatory itself, the Canadian Parliament voted 10,000 dollars for preliminary expenses, which included the search for a suitable site. The statistics of the Weather Bureau gave some preliminary information about cloud and diurnal range of temperature, but it was essential to test the steadiness of telescopic seeing at several selected localities. Mr. W. E. Harper accordingly took a journey for this purpose, equipped with a $4\frac{1}{2}$-inch equatorial; he had made lists of close double stars, and judged the seeing by the angular distance at which they could be separated, also by the regularity of the diffraction rings. Medicine Hat, on a high prairie, has a range of temperature from sunset to sunrise on clear nights of 7°·5 C.; the seeing, on a scale of 5 for perfect conditions, is 2·3. Banff, perched high in the Rocky Mountains, has a range of 9°·2 C., seeing 1·3; Penticton has a range of 7°·2 C., seeing 3·1; Victoria has a range of 3°·8 C., seeing 3·8; Ottawa has a range of 7°·6, seeing 2·6.

It is obvious that none of the first three stations was good enough to justify a move from Ottawa. Before deciding on Victoria, the Directors of Lick, Yerkes, and Mount Wilson were consulted; their replies confirmed the impression that much high-class work, impossible

at Ottawa, could be carried out at Victoria. The site on Saanich Hill, 732 feet high, eight miles north of Victoria, was decided on. The Government of British Columbia generously provided 10,000 dollars for the purchase of land, and agreed to build a road to the summit of the hill. The other expenses, which of course were very large, were provided by the Canadian Government. Dr. Plaskett referred in terms of the highest appreciation to the generosity of the two Governments concerned, and said: "The whole forms one of the largest, if not the largest, single contribution to science ever made by any country, and Canadians should be proud that their country has so splendidly furthered the cause of astronomical research." He also expressed his indebtedness to Dr. King for his enthusiasm in forwarding the scheme of the new Observatory, and his generosity in allowing it to be placed away from Ottawa, where it would have been under his own control.

There is no question that the great success attained at Victoria has been largely due to the skilful design both of the optical and the mechanical parts of the telescope and spectroscope. As our medallist took the leading part in preparing the specifications, it is appropriate to describe them in some detail. He tells us that his aim was to make this telescope as efficient and convenient as any ever built, and much simpler in construction. The disc of the great mirror is of hard crown glass, 72 inches in clear aperture and 13⅝ inches thick; its focal length is 30 feet, its weight 4962 lb.; it has a central hole 10 inches in diameter. It was made at the St. Gobain glass factory, and shipped from Antwerp a week before the outbreak of the Great War, during which the factory was destroyed. It was figured by the firm of J. A. Brashear at Pittsburg; they also made the Cassegrain mirror and the other optical parts. The Cassegrain mirror is 19 inches in diameter, 10 feet in focal length. It is placed 23 feet from the great mirror. The equivalent focus of the combination is 108 feet, the star images being formed 3 feet behind the great mirror; the spectrograph in ordinary use is placed here, and is a permanent fixture; on the occasions (two hours each Saturday evening) on which the public is admitted to view the heavenly bodies through the telescope, a diagonal reflector is inserted between the back of the mirror and the spectrograph, giving a convenient position for the eyepiece at no great height above the floor.

The spectra of faint stars can be obtained by putting a small spectrograph at the principal focus of the large mirror, the Cassegrain mirror being removed. Direct photographs can also be taken here. The dome and the mounting of the telescope were entrusted to the firm of Warner & Swasey, at Cleveland, Ohio. The mounting is in the German form, the telescope being on one side of the polar axis with a counterweight at the other side. The moving parts are 45 tons in weight, but can be manipulated by electric motors with great ease, at either a rapid or a slow rate.

The dome, 66 feet in diameter, is of steel. With a view of enabling it to take up the temperature of the air as quickly as possible, a space is left between the inner and outer plates, through which the air can circulate freely. The temperature of the spectrograph is controlled

by a Callendar recorder, which also gives a graph of temperature changes. I have some slides that show successive stages in the construction, and help us to realise the feelings of satisfaction with which Dr. Plaskett must have watched the telescope of his dreams gradually assuming visible form. We first see the park-like scenery of Saanich Hill; it will be remembered that vegetation plays a useful part in preventing overheating of the soil. We next see the reinforced concrete pier for the telescope and the foundations for the dome. The steel substructure of the dome is seen, and next the steel framework of the dome, as temporarily assembled at Cleveland. Then we see the dramatic moment when the great mirror has been raised on the silvering car, with our medallist standing beside it, and is about to be inserted in the telescope tube. It is an eloquent testimony to the care and skill with which the plans were drawn up and executed that a successful spectrogram of a star was secured within a week of the arrival of the mirror.

Direct photography of the heavenly bodies is not a main feature of the Observatory's work, but a few photographs were taken with the substitution of a Newtonian flat for the Cassegrain mirror, partly as a test of the quality of the images. A slide shows the camera in position, and the screen that covers the opening in the dome, since the open tube would expose the plate to stray light. So far as I know only three such photographs have been published; I show slides of these. Two are in the Society's collection of slides; the clear definition of the dark rifts in the ring nebula in Lyra, and the small star images both in that and in the Hercules cluster, will be noted. The slide of the Orion nebula is copied from a paper print, so it must not be judged so critically as the others. (The originals of the slides will be found in the *Journal* of the R.A.S. of Canada, chiefly in vols. **9** and **10,** 1915, 1916.)

I quote the following from Dr. Plaskett's report: "The driving is perfect, and no trace of any period or irregularity in the following has been detected. The arrangements provided for operating the telescope, for setting on the star, work to perfection, and I have yet to find any part of the design where any improvement could be suggested. In making exposures on star spectra the average time required in changing from one star to the next, from the end of the exposure on one star to the beginning of the next, is less than three minutes, and if the stars are not far apart, is generally only two minutes. . . . When we consider that the moving parts weigh 45 tons, the ease of handling is a remarkable evidence of the perfection of design and workmanship."

The Observatory was completed in the summer of 1918. When the quality of seeing was tested it was found that the favourable verdict pronounced by Mr. W. E. Harper, using a $4\frac{1}{2}$-inch refractor, was fully justified under the more exacting test of the 72-inch mirror. By 1919 January two lists of new spectroscopic binaries, 30 in number, had been published. A few of these were subsequently found to have been noted elsewhere.

Dr. Plaskett saw that a useful class of stars to study was that of the eclipsing variables, since a combination of the radial velocities with

the photometric data enables determinations to be made of the diameters, masses, densities, and the ratio of surface brightnesses of the components. He published data for three such systems in 1919 August: U Ophiuchi, RS Vulpeculæ, and TW Draconis; the second system is remarkable, the fainter star having five times the radius of the brighter one, but only one-third of its mass and one 400th of its density. In U Coronæ (elements published in 1920 June) both components are of type B3, but one has eight times the surface brightness of the other. Some double stars were also examined with the spectrograph: Boss 283 is a wide pair with common proper motion; the fainter star has a very faint close companion; the two brighter stars were both found to be spectroscopic binaries, so that the system contains five stars.

A similar result was found for Boss 497, both components of the visual pair being spectroscopic binaries. The same was found to be true for Boss 1336, 1337.

In addition to the observational work the computation of orbits also went on; so early as 1919 February an orbit was published for H.R. 8170, one of the newly discovered binaries; its type is F8, its period 3·24 days, and semi-amplitude of velocity range 62 km./sec. Dr. Plaskett notes his indebtedness to Professor C. A. Chant for the loan of the prism used in the early work of the Observatory; conditions arising out of the war made it impossible to secure suitable glass for new prisms.

In H.R. 8800, magnitude 6·6, type B, it was noted (1919 March) that the K line of calcium did not share in the large shift shown by the other lines; more will be said later about this phenomenon, which had been noted by Hartmann in δ Orionis as far back as 1904.

The Victoria Observatory was not completed in time to observe Nova Aquilæ of 1918 at its brightest, but good spectrograms were obtained in 1919 and 1920; its magnitude was then 7·0 to 7·5; the colour is stated to have been very blue; the abnormal distribution of light in the spectrum, which alters the appearance of the image with refractors, would not be effective in the reflector. Mr. W. E. Harper discusses these spectra in the *Publications* of the Observatory, vol. **1**, No. 24; he also gives reproductions of spectra of Denning's Nova of 1920, in Cygnus; the sharp H and K lines gave a radial velocity of − 17 km./sec., practically identical with the solar motion in that direction. The absorption bands, on the other hand, gave velocities from − 645 km. on 1920 August 24, to − 1185 km. on September 28. We see here some growth in the belief that the H and K lines arise from diffused calcium in interstellar space, and are unconnected with the particular star in whose spectrum they are seen; but in some cases their appearance may be modified by the lines from the calcium present in the star itself.

At the end of 1921 the attention of the observers at Victoria began to be turned to the stars of type O. At that date our medallist's son, Mr. H. H. Plaskett, published an important paper on the spectra of three stars of this type (*Publications* of the Observatory, vol. **1**, No. 28),

in which he acknowledged the helpful co-operation of his father. The temperature of 10 Lacertæ (Oe5) is given as 15,000° ; that of 9 Sagittæ (Oe5) as 18,500° ; and that of B.D. 35°, 3930 N (Oe) as 22,000°. In the last two stars the absorption lines of Mg^+ are absent ; in the last one those of He^+ have also gone. I show a slide of the diagram, in which the gradual changes of intensity of various lines are shown as we pass from type B8 to Oe. Mr. Plaskett uses these results to obtain observational values of various atomic constants ; these are in excellent agreement with those found from laboratory investigations, thus justifying the assumption of "identical atomic structure, identical electrons, and identical laws of radiation on the earth and in the stars."

These important results induced our medallist to make a systematic examination of all the stars of types Oe to Oe5 that were bright enough for exact spectroscopic investigation. He expresses his indebtedness to Miss Cannon for the preparation of the observing list, which contained 36 stars known to be of these types, and 13 others suspected to be so. One of the latter was a star of the sixth magnitude in the north part of Monoceros, B.D. + 6° 1309, whose position for 1900·0 was $6^h\ 32^m{\cdot}0$, + 6° 13′. It was classified as A5 in Harvard, but as Bop in the Henry Draper Catalogue, in which it was noted that $H\beta$ seems to be slightly bright. We must count it a most fortunate circumstance that Miss Cannon inserted this star in the list, for it proves to be one of the most interesting stars in the sky. The first spectrum obtained, on 1921 December 6, showed that the type was Oe5, and that the star was a binary of high orbital velocity ; accordingly the star was frequently photographed, and by 1922 April 5 thirty spectra had been secured. The period appeared to be a fortnight, but this indicated such abnormal masses that it was thought it might actually differ little from one day. Accordingly photographs were taken at different hours of the night, which negatived the short period and showed that a fortnight was right. The minimum masses now come out 75·6 and 63·3 times the sun, so that this is by far the most massive system known. The semi-major-axis is 0·6 astronomical units, and the velocities 206 and 247 km./sec. The eccentricity is small, 0·035 ; the system is receding at the rate 24 km./sec., of which Dr. Plaskett estimates that 2·8 may be ascribed to the Einstein gravitational shift, while about 16 is due to the solar motion, the star being in the region of the antapex ; further, at the distance of 9300 light-years estimated by Dr. Plaskett, the de Sitter shift, of the presence of which the radial motions of the spiral nebulæ give evidence, would amount to about 1 km.

The estimate of the distance of the star was made in two ways : first, by Eddington's curve connecting mass and absolute magnitude ; secondly, by using assumed values of surface brightness and temperature of O-type stars derived from Plaskett's own researches. The two methods agreed in giving absolute magnitude − 6·3 for the combined light of the pair. Taking its visual magnitude as 6·06, the distance is 2860 parsecs or 9300 light-years. The density was estimated as 0·01, the diameters as 19½ and 18 times the sun's, the luminosities 15,000 and 12,000 times the sun's. Our late Fellow, Mr. Scriven Bolton, drew

two pictures for the *Illustrated London News* from these data, of which I show a slide ; he has added huge coronæ, which are of course imaginary, but stars of such immense luminosity and low density would be likely to have external appendages.

The masses given above were minimum masses, based on the assumption that we see the orbit edgewise. In this case each star would eclipse the other at intervals of about a week, which would produce fluctuations of nearly a magnitude in the combined light. For the stars to pass clear of each other at conjunction with the dimensions given above, i must differ from 90° by at least 17°, which increases the masses to 86 and 72. Dr. Plaskett assumes that no eclipses take place, but I do not regard this as certain. Apparently no measures of the light have been made since the duplicity was known, and observations made before that date give a few abnormally faint values. Thus the star was observed twice in the Leipzig zones of the *Astr. Gesells.* Catalogue, the two estimates of magnitude being 6·0 and 7·5 ; also in the Harvard determinations, 1879 to 1881, the three estimates are 6·0, 5·8, and 7·1. Dr. B. A. Gould included it in his list of suspected variables from the fact of some discordances in the published magnitudes. It would seem to be worth while to examine it carefully at the times when partial eclipses are possible, in view of the more exact information that these would afford of the masses and diameters of the stars.

It is not to be expected that this star would have sensible proper motion, but it seemed to me to be worth while to collect all the observations that I could find. They are summarised in the following table, the systematic corrections of Boss having been applied where they were available ; all observations are reduced to the equinox of 1875·0 :

Right Ascension.	N. Decl.	Catalogue.	No. of Obs.	Mean Date.
h m s	° ′ ″			
6·30 42·48	6 14 20·4	Lalande	1	1794
41·99	17·9	Pulk., Paris, etc.	7	1858·7
42·04	18·2	Greenw., Leipz., etc.	6	1884·5
42·02	18·5	Kust., Toul., Campid.	18	1896·7
42·93	18·2	Greenwich, Lick	4	1923·0

I inferred from these figures that the total motion could not greatly exceed 1″ per century ; I subsequently found that Mr. J. A. Pearce gave it as 1″·14 per century ; he did not name the authority for this value.

The fact that the H and K lines in this star were stationary, giving the uniform velocity of + 16·0 km./sec., which is almost exactly that due to the sun's motion, practically established the conclusion that these lines arise from gas distributed through interstellar space, not from a cloud surrounding the star itself ; for it is incredible that any cloud in the vicinity of these enormous masses, moving with such high velocities, could remain absolutely unaffected. This was a result of very high importance. Dr. Plaskett discussed the question very fully in a paper in *M.N.*, **83**, 80 (1923). He showed that the calcium pro-

ducing the stationary lines must be external to the stars in whose spectra they were observed. He suggested that while the calcium clouds might be spread generally through interstellar space, the production of the spectral lines was probably limited to the regions adjacent to the stars of high temperature, where the gas was ionized by their radiation. It will be remembered that Dr. O. Struve read a paper before this Society last April, in which he suggested that the intensity of these spectral lines might be used as a measure of the distance of stars in the more remote regions of our stellar system; on the assumption of the truth of this principle, he obtained a position for the galactic centre, close to that obtained by Professor Shapley in an entirely different manner. In the discussion that followed the paper the only doubt expressed as to the safety of using the principle was the suggestion that the distribution of the diffused gas might be far from uniform. Dr. Plaskett put this doubt at rest in a remarkable paper which Professor Eddington described at the meeting of the Society last November; his results seem to establish clearly that the average distance of the absorbing calcium cloud is half that of the star in whose spectrum it is observed; this would indicate that the amount of absorption varies directly as the distance, not according to an exponential formula, as had been suggested.* We are thus placed in possession of a very powerful method for measuring the distances of the more remote stars of types B and O; the work of our medallist has played a large part in the establishment of this method, though like many results in astronomy it is due to the combination of the observations and discussions of several individuals.

I think it well to say something about another spectroscopic binary of type O8·5*n*; this is H.D. 1337 = Boss 46; 1900 R.A. $0^h\ 12^m\cdot5$, N. Decl. 50° 53′, which is investigated by Mr. J. A. Pearce in *Publ. of Victoria Obs.*, vol. iii., No. 13. This has many points in common with the Plaskett star; their distances from the sun, absolute magnitudes, temperatures, eccentricities, orbital velocities, proper motions (each about 1″ per century) are all practically identical; but the masses of the components of Boss 46 are less; they are 36·3 and 33·8 in terms of the sun; in this case the masses are exactly determinable, owing to the fact that partial eclipses take place, as was recognised by Professor Guthnick in 1919; the loss of light is less than 0·2 magnitude. The star had been announced as a spectroscopic binary at Mount Wilson in 1916, which led Guthnick to examine it with the photo-electric cell. The radii of the components are 23·8 and 15·5 in terms of the sun; they revolve almost in contact with each other in 3·52 days, and are of markedly ellipsoidal shape, owing to tidal action. Their densities are 0·0027 and 0·0091 in terms of the sun's, thus supporting Dr. Plaskett's assumption of 0·01 for the Plaskett star as being of the right order.

Our medallist has given special attention to the stars of type O;

* A note by Dr. Plaskett in *Popular Astronomy* for February 1930 states: "The investigation establishes the fact that the interstellar calcium is not only uniformly distributed through space, but partakes of the general galactic rotation."

he notes that they are extremely rare in space, and all are very distant from us; by combining the radial motions with the proper motions, he has deduced the mean parallax of the O-type stars observed as 0″·0011; the corresponding distance is 3000 light-years; the average absolute magnitude is − 4, implying brightness 4000 times that of the sun; this is several times as great as that of any other spectral class, and shows that this is an exceptional and rare type. The masses range from 10 to 80 times that of the sun, the average being about 40. They are the hottest stars known, their temperatures ranging from nearly 20,000° to about 30,000°. Dr. Plaskett estimates that there are twenty times as many A stars as B stars, and about twenty times as many B stars as O stars; we shall soon see that his observations of these stars give important information about the rotation of the galaxy.

A research of much interest is that on the star *v* Sagittarii, an orb which has been the occasion of much discussion. Miss Cannon conjectured that its spectrum might be a composite one, arising from three separate bright bodies. Miss Maury described it as having a primary F2 spectrum with a B8 spectrum superposed on it, the latter at times becoming dominant. At these times the hydrogen lines are double, but the secondary is always on the violet side, with a relative separation of 280 km./sec., if viewed as a velocity. It was from a misunderstanding of this last statement that Dr. Ludendorff was led to postulate the binary character of the star, with the unparalleled minimum masses of 260 and 54 times that of the sun. It was fatal to this suggestion that the doubling of the hydrogen lines was noted by Miss Maury to occur near the times of zero radial velocity. Plaskett's work, indeed, shows that the star is a spectroscopic binary, as had been announced by Wilson twelve years earlier; Wilson's results gave a period of 138 days, and radial motion varying from + 60 to − 35 km./sec. All the various types of spectral lines mentioned above share in the same periodic oscillation, indicating that they all belong to the same star, and that only one star of the pair, whose existence is demonstrated, is sufficiently luminous to give a visible spectrum; it is therefore clearly proved that a single star can give a spectrum of a composite character; Dr. Plaskett describes it as a super-enhanced spectrum of type A2, with a B-type spectrum superposed on it. The helium lines of the latter spectrum are narrow, strong, and well-defined, possessing the *c* characteristic. The hydrogen lines have "satellite" lines, that are always on the violet side, at constant distances from their primaries; hence they do not belong to a second star revolving round the first, as Ludendorff supposed; it is conjectured that they may be due to hydrogen ejected from the star, as in the novæ; if so, the indicated velocities of ejection in the direction of the solar system are 150, 200, and 300 km./sec.

Dr. Plaskett notes that the star must be a massive one, though not approaching Ludendorff's estimate; assuming that the primary has twice the mass of the companion, which is reasonable when no trace of the second spectrum is seen, he finds the minimum mass of the bright star to be twenty-eight times that of the sun.

I pass now to Dr. Plaskett's contributions to the intensely interesting subject of the rotation of the galaxy. The general idea of galactic rotation is not a new one. The astronomical text-books that I read in my youth nearly all supported Mädler's view that the Pleiades are the centre about which the sun and its neighbours are moving. This view did not hold the field for very long; an epoch succeeded in which doubt was felt whether there was any definite centre of the stellar movements. The discovery by Kapteyn, early in the present century, of the two stellar drifts suggested to Professor Turner the idea that these drifts consisted of the stars respectively approaching and receding from the centre, their orbits being postulated as very elongated, like those of the comets of long period, so that the motion was mainly radial; this supposition led him to locate the centre in the feet of Gemini, R.A. $6^h\,16^m$, N. Decl. 12°, its distance from the sun being 30 parsecs. The view that now holds the field was put forward by Dr. Oort in 1927. He was, I think, guided to it by the high rotational velocities that are indicated by the spectroscope in many of the spiral nebulæ; this suggested that the rotational speed in any region of the galaxy would be much greater than the peculiar speeds of the individual stars in that region. It may help us to picture the method if we consider a number of passengers, walking in various directions on the deck of a steamer, while the steamer itself is moving in a circle round an island a mile or two away, its speed being some ten times that of the walkers. Then all our previous endeavours to find the centre have been based simply on the movements of the walkers on the deck, disregarding the much higher speed of the steamer. It is clear that we can get no idea of the latter by consideration of the movements of the passengers on the deck. We must make observations of other steamers going round the same centre. In the astronomical problem we must consider the movements of bodies that are as distant as possible from the solar system—that is, the stars of types O and B. In these distant objects the proper motions across the line of sight are too small to determine with accuracy, and we have recourse to the radial velocities. It is clear that if the whole system were revolving as a rigid body there would be no relative radial motion; but actually the force to the centre and the velocity are functions of the distance from the centre. Dr. Oort gave a formula for the radial motion in different regions; the most important term of his formula contains as a factor $\sin 2(l - l_0)$, where l, l_0 are the galactic longitudes of the star and of the centre of rotation; Dr. Plaskett analysed the radial motions of the stars of types B and O observed at Victoria Observatory (*M.N.*, **88**, 395.) The different groups into which he divided them gave accordant results; the position indicated for the centre of rotation was galactic longitude 324°·5 (the origin being the ascending node of the galaxy on the equator of 1900). This agrees with the position found by Oort, and also with that given by Professor Shapley for the centre of the system of globular clusters. This seems to demonstrate beyond a doubt that these clusters are true appendages of the galactic system, not completely independent objects like the spiral nebulæ. The distance of this centre from the sun is given by

Shapley as 13,000 parsecs. Professor Eddington deduced 330 km./sec. as the sun's velocity in its orbit round the centre (*M.N.*, **88**, 330); the period of revolution would be 200 million years, which happens to be of the same order as the period given by Professor Turner for its revolution round a much smaller orbit with a lower velocity.

The position found for the galactic centre is R.A. $17^h\ 30^m$, Decl. $-31°$ (1900). This is near the junction of Sagittarius, Ophiuchus, and Scorpio, and is in the rift between the two branches of the galaxy. Professor Shapley suggests with great probability that the rift is caused by obscuring clouds, which may conceal the densest part of the galaxy. This suggestion would make it easier to imagine the presence of the necessary mass in the centre of the system. Professor Eddington gives the total mass necessary to control the motion as 270,000 million suns.

It would not be right in giving an account of Dr. Plaskett's work to omit mention of the great help that he received from his staff of assistants; the names of Mr. W. E. Harper, Dr. R. K. Young, Mr. J. A. Pearce, and Mr. H. H. Plaskett perhaps occur the most frequently. The two first mentioned contributed a valuable catalogue of 1100 spectroscopic parallaxes, the calibration curves for the spectral lines employed being drawn from their own researches, so that the catalogue should be quite independent of those published elsewhere.

I have only been able to trace a few of the numerous researches that our medallist has carried out, but I have tried to make them typical of his work in general. The actual conferring of the medal is postponed till the May meeting, at which Dr. Plaskett has promised to deliver the George Darwin Lecture. I am sure that we all join in the hope that he may derive some encouragement from the evidence which the award of the medal affords that his work is highly appreciated by the Society, and in the further hope that he may be able to continue that work for many more years.

Election of Officers and Council.

The following Fellows were elected as Officers and Council for the ensuing year :—

President.

A. C. D. Crommelin, Esq., B.A., D.Sc.

Vice-Presidents.

Sir Frank Dyson, K.B.E., M.A., D.Sc., LL.D., F.R.S., Astronomer Royal.
E. B. Knobel, Esq., D.Sc.
H. F. Newall, Esq., M.A., D.Sc., F.R.S.
Rev. T. E. R. Phillips, M.A.

Treasurer.

J. H. Reynolds, Esq.

Secretaries.

Herbert Dingle, Esq., B.Sc., Assistant Professor of Astrophysics, Imperial College of Science and Technology, South Kensington.
W. M. Smart, Esq., M.A., D.Sc.

Foreign Secretary.

H. H. Turner, Esq., D.Sc., D.C.L., F.R.S., Savilian Professor of Astronomy, Oxford.

Council.

J. A. Carroll, Esq., M.A., Ph.D.
S. Chapman, Esq., M.A., D.Sc., F.R.S., Chief Professor of Mathematics, Imperial College of Science and Technology, South Kensington.
L. J. Comrie, Esq., M.A., Ph.D.
A. S. Eddington, Esq., M.A., D.Sc., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.
Alfred Fowler, Esq., D.Sc., F.R.S., Yarrow Research Professor of the Royal Society, Imperial College of Science and Technology, South Kensington.
W. M. H. Greaves, Esq., M.A.
F. J. Hargreaves, Esq.
John Jackson, Esq., M.A., D.Sc.
Harold Jeffreys, Esq., M.A., D.Sc., F.R.S.
E. A. Milne, Esq., M.B.E., M.A., M.Sc., F.R.S., Rouse Ball Professor of Mathematics, Oxford.
B. M. Peek, Esq., M.A.
F. J. M. Stratton, Esq., D.S.O., O.B.E., M.A., Professor of Astrophysics, Cambridge.